1000 feet front. The shore is paved from low-water mark, and furnished with floating wharves, which rise and fall with the river. Cincinnati is bounded on the south by the river, and on the north, east and west by hills, 300 to 400 feet high, which form the walls of an amphitheatre, with the business section of the city lying at their base, situated on a series of terraces.

Location central in the Ohio Valley. Cincinnati is central to the Ohio Valley. Pittsburg, where the Ohio River is formed by the junction of the Monongahela and the Allegheny, is 960 miles from the Mississippi River; the distance from Pittsburg to Cincinnati is 458 miles. Lake Erie is 500 miles from the sources of the Kanawha and the Tennessee; Cincinnati is about half-way between, and almost on the line. The principal tributaries of the Ohio are the Muskingum, Great Kanawha, Big Sandy, Scioto, Miami, Green, Kentucky, Wabash, Cumberland and Tennessee Rivers. About 210,000 square miles are drained by the Ohio and its tributaries, and Cincinnati holds the strategic position in this region.

Connections with the East. The city is connected by navigable rivers and by railroads with the ocean and with the interior river coast. Of the great railroad lines which cross the passes of the Appalachians, all except the direct lines of the New York Central pass through Cincinnati. The Norfolk and Western, the Chesapeake and Ohio, the Baltimore and Ohio, and the Pennsylvania connect Cincinnati with the East.

Geographical boundaries of Cincinnati. Geographically speaking, Cincinnati includes more than the limits of the city, since Cincinnati occupies only a part of the wide valley of a former mature river. The older portion of the city, nearest the river, is a depressed area, 300 feet below the general level of the country, somewhat semi-circular in shape, bounded as stated above. A smaller half-basin, similar in shape, is occupied by Covington and Newport, Ky., towns lying just across the river from Cincinnati, this half-basin being intersected by the Licking River and semi-circled by hills. In a very remote period, the Walnut Hills area, one of Cincinnati's eastern hilltop suburbs, was directly connected with the Kentucky highlands, lying east of Newport. The Price Hill area, a western hilltop suburb of Cincinnati, was connected with the south-lying hills of Kentucky. The Licking River then flowed northward toward Hamilton. These hills

were cut apart, and the course of the Ohio at Cincinnati today was brought about, as a result of later drainage adjustments.

Cincinnati, Covington and Newport commercially one city. From a geographical point of view, then, Cincinnati, Covington and Newport are all one, and they are so treated in this discussion. Commercially, also, Covington and Newport are suburbs of Cincinnati, though legally they are distinct municipalities. Separated from Cincinnati by the Ohio River only, over which stretch five bridges, and within twenty minutes' reach of the city's business center, the majority of these Kentucky citizens have their business interests in Cincinnati, are employed in her numerous industrial establishments, and are largely dependent on her for their prosperity. While these towns have a creditable number of manufacturing establishments, they make large use of Cincinnati's transportation facilities in shipping their products. Almost from the founding of Covington and Newport, their development has been closely associated with that of Cincinnati, and geographically these towns are "South Cincinnati," as they are sometimes called.

The Founding of Cincinnati

Symmes' Purchase. The founding of Cincinnati, or Losantiville, as it was originally called, was due primarily to the attraction of the Miami Valley's rich soil. Major Benjamin Stites, of Brownsville, Pa., passing through this region, was so impressed with its fertile fields, fine forests and beautiful streams, that he decided to found a permanent settlement in the neighborhood. In partnership with Judge John Cleves Symmes, of Trenton, N. J., Major Stites shortly obtained possession of 1,000,000 acres of this Miami country, bordering on the Ohio River.

Advantages of the Miami region. River valleys always attract settlers, and this Miami Valley is a peculiarly advantageous location. It is not far vertically from sea-level, the country in general is about 500 feet above sea-level, the surrounding hills about 200 to 300 feet higher. Furthermore, it is well watered. The Licking River joins the Ohio from the Kentucky side, just opposite Cincinnati, while at the time of the first settlement the Great and Little Miami, which drain this Miami country and are tributary to the Ohio, were bounded for many miles by land of unsurpassed fertility.

Grain grew abundantly in this region—wheat, rye, corn, buckwheat, barley, oats and hemp—tobacco was produced of a quality much superior to Virginia tobacco, while fruits of all kinds commonly found in a temperate zone were grown to advantage. Game was plentiful, and the rivers were well stocked with fish.

The rock formations of this region consist of alternating layers of blue clay-marl and blue or lead-colored fossiliferous limestone, bituminous shale and fine-grained sandstone, covered with black mold and amber loam, a combination which makes a very fertile soil. The wells and springs afforded a very pure limestone water, and the water of the Ohio does not contain a noticeable amount of mineral matter.

Three settlements. Three settlements were made on the Ohio at about the same time in 1788: one at Columbia, near the mouth of the Little Miami; one at North Bend, near the Great Miami; one at Losantiville, afterwards called Cincinnati, opposite the mouth of the Licking. At first the settlements at Columbia and North Bend grew more rapidly than the Losantiville settlement, this more rapid growth being due in considerable measure to the fact that temporary fortifications had been built at North Bend and Columbia, for protection against the Indians, while at Losantiville there was no military protection.

Building of Fort Washington. In the spring of 1789 there was a flood on the Ohio, and the fortifications at North Bend and Columbia, being situated on low ground, were submerged.[2] Major Doughty was sent out by the federal government to investigate conditions, and after studying the topography of the region, he decided upon Losantiville as the most available place for a permanent fortification, by reason of the river's high bank. Accordingly, Fort Washington was built at this point, this fort being sufficiently large to accommodate 1500 soldiers. After Fort Washington was completed, the settlers at North Bend and Columbia began to throng to Losantiville, which led Mr. King to remark, in his *History of Ohio,* that "whatever Cincinnati may have suffered since by floods, she doubtless owes her start to that of 1789."[3] In 1790 the name of the settlement was changed from Losantiville to Cincinnati by Judge Symmes, this name being authorized by Governor St. Clair.

[2] Rufus King, American Commonwealth Series, *Ohio,* 1891, p. 212.
[3] *Ibid.,* p. 213.

Influences in early growth. Judging from conditions today, the region about North Bend would be the proper location for a large city, since it is near the mouth of the Great Miami, which drains such a large fertile region to the north. But the influence of this recent stream, in reference to the Ohio, is secondary to that of the old stream valley above referred to. Cincinnati lies in the valley of the Old Licking, where the Licking, from the Kentucky side, joins the Ohio, which is of much later origin in this part of its course. A very few miles up the river the Little Miami empties into the Ohio. The valley of the Licking, and the turnpikes in Kentucky, led settlers easily from the Kentucky regions, which were becoming thickly settled at that time, while large numbers came later from the east by way of the Ohio.

Early Years of the Settlement

Indian depredations. During the first few years of the settlement, no attempt was made to establish any industries. Fear of the Indians kept the settlers together, and their efforts were confined almost exclusively to agriculture. The Peace of Greenville was concluded in 1794; fear of savage depredations thus being removed, industrial progress began.

Ferry and packet line established. In 1792 a ferry was established opposite the Licking, and legal rates were fixed by Governor St. Clair.[4] In 1794[5] a regular packet line was established to Pittsburg, while keels, flatboats and barges carried the farm products of the rich Miami country down the river to New Orleans, and in turn brought supplies from New Orleans to Cincinnati. A good road led down from Newport to Lexington, the center of Kentucky's rich farm region, and the farm products of Kentucky were brought to Newport, ferried over to Cincinnati, transferred to boats and carried down the Ohio to the Mississippi.

Cincinnati's Rapid Industrial Growth

Population and manufacturing statistics. Though population figures are not a sure index of a city's commercial standing, yet a very rapid increase in population is usually an indication of

[4] W. H. Venable, *Cincinnati and Hamilton County*, p. 65.

[5] Ohio Archeological and Historical Society Publications, vol. vi, 1900, p. 241.

industrial progress, hence Cincinnati's population statistics are of interest. Below are the figures from the beginning of the nineteenth century to the last census, 1910 (including Covington and Newport); also the manufacturing statistics from 1840 to the present time:

	Population	Manufactures		Population	Manufactures
1800	856		1860	187,561	$56,995,062
1810	2,953		1870	255,831	70,000,000
1820	9,642		1880	305,292	145,947,280
1830	26,289		1890	358,197	218,751,545
1840	48,364	$16,366,443	1900	397,141	169,498,035
1850	130,738	46,189,279	1910	448,012	206,288,000[6]

INDUSTRIAL GROWTH FROM 1800 TO 1850

Reasons for Cincinnati's rapid industrial growth. During the first half of the last century, Cincinnati grew more rapidly than any other city in this country. In addition to the general reasons for the prosperity of the Miami country, there were also special reasons why Cincinnati should become a manufacturing center. Raw materials for manufacturing were easily accessible. Clays for making brick and pottery were abundant in the lower part of the town, limestone was present in large quantities in the beds of the Licking and the Ohio, and the materials for glass making were at hand in great abundance. Wood was plentiful in the neighborhood, and coal was brought down the river at a very cheap rate. Iron ore from the Hanging Rock region was easily accessible. Moreover, Cincinnati had splendid harbor facilities. In 1815 the prediction was made by Dr. Drake[7] that Cincinnati was to be the future metropolis of Ohio, by reason of its location opposite the Licking, and its great expanse of shore, with no shoals or reefs to prevent the landing of boats.

Growth from 1800 to 1820. During the first twenty years of the nineteenth century, Cincinnati's population increased about thirteen-fold, and the city became known as, next to Pittsburg, the greatest place for manufactures and mechanical operations on the river.

Influence of transportation lines. This commercial progress was doubtless largely due to the fact that during this period steam-

[6] Approximate.

[7] Daniel Drake, *Picture of Cincinnati*, 1815, p. 231.

boats came into general use, thus greatly increasing the facilities for river transportation. Roads also played their part in this industrial development. In 1817 The Cincinnati and Hamilton Turnpike Company was incorporated, also The Cincinnati and Dayton Turnpike Company. At this time there were roads connecting Cincinnati with Detroit, Mich., Vincennes, Ind., New Orleans, La., Greenville, O., Louisville, Ky., Chillicothe, O., Williamsburg, Ky., and Pittsburg, Pa.

Demand for manufactures. Cincinnati was primarily impelled to become an industrial center by the growing demand for manufactured articles on the part of the farmers. The rich areas of the Miami region were becoming thickly settled, and the regions along Zane's Trace were rapidly developing; consequently the farmers needed various articles. It was an expensive and difficult task to transport manufactured articles across the Appalachian mountains. Accordingly, Cincinnati began to supply the home demand in different parts of Ohio and Indiana, since access to Cincinnati was easy by way of the Ohio and the roads mentioned above.

Growth during 1820 to 1840. This was a period of very rapid progress. The population increased five-fold; in twenty years Cincinnati grew from a town of about 10,000 inhabitants into a city, with a population as large as that of Springfield or Youngstown today. In those early days this was an unparalleled growth.

Influence of canals. In 1840 the value of Cincinnati's manufactures was $16,366,443.[8] This industrial progress was largely the result of the building of canals, connecting Cincinnati with the East. The Erie Canal was completed in 1825, joining Lake Erie and the ocean. In 1830 the Miami Canal, which was to connect Cincinnati and Toledo, reached Dayton;[9] in 1845 it reached the lake. Between 1830 and 1840 there were constructed also the Ohio Canal, connecting Lake Erie and Portsmouth, and the Whitewater, which connected Harrison and Cincinnati. These canals furnished an easy and reliable means of communication. At that time there were no railroads in the West. Rivers were the chief means of transportation, and Cincinnati exceeded all other Western cities in the number of her boats. Vessels ply-

[8] *Ohio Statistics*, 1880, p. 768.

[9] *The Ohio Gazeteer*, Columbus, 1839, p. 258.

ing between Cincinnati and New Orleans carried immense quantities of grain and other farm products down the river, and brought back supplies for the grocery trade. The canals filled in the gaps in the transportation system. When the Upper Ohio was not navigable, goods were brought from New York by the Hudson River to Buffalo, then by the lake and the Ohio Canal to Portsmouth and on down the river.

Highways. During this period several pikes were built. In 1840[10] fourteen macadamized roads proceeded directly from Cincinnati, connecting the city with all the important towns of Ohio. The Dayton and Springfield Road, by its connection with the National Road at Springfield, connected Cincinnati with Wheeling and Baltimore. Through Baltimore, Cincinnati had access to Virginia and the Carolinas. Thus, by means of the river, the roads and canals, Cincinnati had access to the north, east and south.

Public improvements. In the decade ending with 1840, extensive public improvements were made in the city. The shore of the river was paved from low-water mark, and floating wharves were built. A good system of street-lighting and a well-equipped city waterworks were installed.

Slaughtering and meat-packing center. Cincinnati was foremost in the slaughtering and meat-packing industry at this time, being known as "the pork shop of the Union." Sir Charles Lyell, a distinguished Englishman who visited Cincinnati about 1840, bestowed upon the rich merchants of the city the rather slighting title of "Pork Aristocracy."[11]

From 1840 to 1850. In the next decade, Cincinnati made the most phenomenal growth of any city in the country. Her population increased over 80,000, and the value of her manufacturing products increased almost three-fold.[12] In 1850 Cincinnati was the fifth city in the Union in population. Her manufacturing products, which at that time constituted more than one-half the business operations of the city, yielded a profit of $25,000,000 yearly, almost one-half the whole amount obtained. The manufactures at this time included almost every known variety of industry. Among the largest items were those of packing prod-

[10] Charles Cist, *Cincinnati in 1851*, 1851, p. 131.

[11] Sir Charles Lyell, *Travels in North America*, New York, 1845, vol. ii, p. 61.

[12] *Ohio Statistics*, 1880, p. 768.

ucts, alcohol and spirits, boots and shoes, clothing, foundry and engine shop products, and furniture.

Influence of transportation lines. The influence of the canals was greatest during this period. The railroad fever had seized the citizens of Ohio, but there were very few railroads in operation previous to 1850. A road was completed from Cincinnati to Springfield in 1846, and by 1848 through steam connection was made between Cincinnati and Sandusky.[13] Within the next decade several railroads were completed, but preceding 1850 canal shipping was the most important factor in Cincinnati's growth.

INDUSTRIAL GROWTH SINCE 1850

From 1850 to 1870. During the decade preceding the Civil War, Cincinnati's development was naturally retarded by war agitation, in common with other cities all over the country; her population increased about 57,000, but the value of her products increased less than $11,000,000. In the Civil War period, her population increased about 67,000, while the value of her products increased only about $14,000,000.

1870 to the present. Since 1870 Cincinnati's growth, both in population and manufactures, has been steady and consistent. From 1870 to 1880 her manufactures more than doubled, the influence of the Civil War having disappeared. In the next decade her manufactures increased satisfactorily. During the decade ending in 1900, the value of her manufactures decreased, due probably to the panic of the nineties; in the last decade the manufactures show a pleasing increase. Since 1850 the value of Cincinnati's manufacturing products has increased about four and a half-fold, while the gain in population has been almost three-fold.

Influence of the railroads. This progress has doubtless been largely due to the building of railroads. The day of the canals was over by 1850. In 1851 Cincinnati and Cleveland were connected by railroad; in 1852 a railroad was built from Cleveland to Pittsburg.[14] In 1853 the Baltimore and Ohio Railroad reached the Ohio valley; in 1857 a road was built, connecting Cincinnati with St. Louis. The year 1857 was also marked by the completion of the Ohio and Mississippi Railway, which connected Cin-

[13] Ohio Archeological and Historical Society Publications, vol. ix, 1901, p. 190.
[14] *Ibid.*, p. 190.

cinnati with five of the states along the southern seaboard. In 1859 the Louisville, Cincinnati and Lexington Railway (afterwards the Louisville and Nashville) was completed to Nashville. By 1870 Cincinnati was connected by railroad with Baltimore, Philadelphia, New York, Toledo, Chicago, St. Louis, Louisville, Lexington, and several important southern cities. Since that time railroads have been multiplied, and facilities for river transportation have been greatly increased; as a result, Cincinnati's manufacturing establishments have multiplied many-fold, and commerce has steadily grown.

The Cincinnati of Today

Population statistics. What place is held by the Cincinnati of today, in comparison with other large cities? According to population statistics (including Covington and Newport), Cincinnati is the tenth city in the United States, and second in Ohio, with a population of 448,012. Twenty years ago Cincinnati stood seventh, with a population of 358,197. According to population statistics, Cleveland, Ohio's leading city, ranks as the sixth city in the United States, with a population of 560,663. Twenty years ago Cleveland held tenth place, with a population of 261,353.

Manufactures. In regard to manufactures, however, Cincinnati is a close rival to Cleveland. In 1910 Cincinnati's manufactures (including Covington and Newport) amounted to $206,288,000. Cleveland's manufactures amounted to $271,961,000, having more than doubled in the last decade. But Cleveland's manufactures per capita amounted to $485; Cincinnati's per capita manufactures amounted to $464.

Cleveland has an advantageous location on the Great Lakes, which are the natural highway of the commerce of the Northwest. Furthermore, a great part of Cleveland's manufactures consists of steel and allied products. In 1890 $30,000,000 of Cleveland's $113,000,000 of manufactures were steel products. In 1900 her steel manufactures had increased to $51,000,000, over one-third of her products. In 1905, which is the latest date for which detailed census reports are available, $72,000,000 of Cleveland's $172,000,000 of manufactures consisted of steel products. The supply of ore in the Lake Superior region is not inexhaustible.

When this supply is used up, Cleveland's chief industry will be destroyed, and her rapid progress will cease, unless she finds some way to adjust herself to the changed conditions.

Cincinnati's manufactures are general. Her chief industrial products rank as follows: Distilled and malt liquors, clothing, slaughtering and meat-packing products, foundry and machine shop products, boots and shoes, printing and publishing, carriages and wagons, tobacco, cigars and cigarettes, and furniture. Cincinnati produces more soap than any other city in the country, and is foremost in the manufacture of vehicles. Ohio, in 1900, held third place in the production of liquors in this country, and 76 per cent of the distilled liquors produced in the state come from Cincinnati. Over one-half the clothing manufactured in Ohio also comes from this city.

For many years Cincinnati was the packing center of the country, but as the center of corn-growing moved westward, she yielded her preëminence to Chicago, though her packing interests are still very large.

In the manufacture of pottery, Cincinnati's position is eminent. Rookwood Pottery, which was founded about twenty-five years ago by a prominent woman of Cincinnati, has now become world-famous; its products go to all the countries of Europe, and are acknowledged to be unique. This pottery is made largely of native clays, though some clays are imported.

The Cincinnati of the Future

What of the future? Is it probable that Cincinnati will ever regain her place as the leading city of Ohio in population? What advantages has Cincinnati over other cities, which should enable her to make more rapid progress along industrial lines?

CINCINNATI'S ADVANTAGES

Ample room for growth. Cincinnati has abundant space for expansion. The encircling hills offer ample room for growth. Moreover, the suburbs can be located within easy reach of the city's business center by trolley and railroad train.

Good climate. The city is favored in climate, from an industrial point of view. The surrounding hills protect the city from

destructive winds, and modify the effect of storms; Cincinnati is not visited by the Western tornadoes, or the storms of the North and South. The wind direction is prevailingly from the southwest. Moreover, the temperature maintains a happy medium; her winters are comparatively mild, the mean temperature being 33.6°; her summers are rarely extremely warm, the mean temperature being 73.5°. The average rainfall for the year is 48.02 inches, and the precipitation is well-distributed seasonally, summer being the wettest season and autumn the dryest. Cincinnati's climate is healthful, the annual death rate is 20 per 1000. Strangers coming to the city become acclimatized very readily.

Public improvements. An abundant supply of water, with a thoroughly modern and scientific filtration plant, excellent shipping facilities and a fine street-lighting equipment, are valuable industrial assets of which Cincinnati can boast.

Central location. Cincinnati's location with respect to other large cities is quite advantageous. It is about 750 miles from New York, 600 miles from Washington, 300 miles from Chicago and St. Louis, 640 miles from Baltimore, 250 miles from Cleveland. Furthermore, Cincinnati is the nearest large city to the center of population (which, according to the last census, is located near Bloomington, Ind.), and is therefore a good base for supplies.

Grain and coal center. Having a very extensive distributive outlet to all the Southland, Cincinnati has become one of the country's most important grain centers. This city is, in addition, the soft coal center of the United States, taking into consideration production, availability and geographical location. Ohio, Michigan, Illinois, Indiana, Kentucky, Tennessee, Alabama, Pennsylvania and West Virginia furnished 85 per cent of the total amount of coal produced in the United States in 1909;[15] these coal regions are within a radius of 300 miles from Cincinnati. In 1910 Cincinnati received more coal than ever before in her history, 20 per cent more than in 1909. The improvement of the Ohio River, particularly the building of Fernbank Dam, and the extension of railroad lines to the east, west and south, will combine to give Cincinnati still greater advantage in location in respect to the availability of cheap fuel.

[15] U. S. Government Report on "The Production of Coal," 1910.

RIVER IMPROVEMENT

Shipping facilities. Cincinnati's advantageous railroad connections have already been mentioned. The city is connected with the south, east and west by fifteen railroads. But the river has always been the chief factor in Cincinnati's progress. The harbor at Cincinnati is very superior, the current of the river is about 3 miles an hour, and there are no shoals or reefs to prevent the landing of boats.

Fernbank Dam. This dam, a government project just recently finished, is destined to have an important effect on the city's future commercial progress. Heretofore the low stage of water in the summer months has frequently been the source of great inconvenience and a great loss of money to manufacturers. This dam affords a lake for harbor purposes the year round at Cincinnati, and will produce a large amount of water-power for electrical energy, which can be utilized for manufacturing purposes, and will therefore be of very great value to the city.

Improvement of the Mississippi system. Fernbank Dam is but one of the many dams which the government is now building or planning to build. It is estimated that, in order to secure a 9-foot stage from Pittsburg to Cairo, Ill., about seventy-five dams will be required, at a cost of about $75,000,000. At the present time the Ohio River is navigable at Pittsburg, on an average, only about eighty-one days during the year. Since the region about Pittsburg is one of the greatest, if not the greatest, freight-producing center of the country, this is a serious detriment. It is planned, by means of collapsible dams, to store up a supply of water during flood times, and thus make navigation possible the year round. By holding back the waters of the Monongahela, Kanawha, Allegheny, Youghiogheny, and the numerous small tributaries of the Ohio, the disastrous effects of floods will also be lessened, and a large amount of power will be developed at the dams. With the 9-foot stage, it will be possible to use less powerful steamers in bringing barges down the river, each boat taking fewer barges, with less capital invested at less risk.

The freight carried by the Ohio River system forms the bulk of the Mississippi system tonnage. It has been estimated that with the improvement of the Mississippi River system, and the completion of the Panama Canal, freight can be sent by water

down the Ohio and the Mississippi Rivers, through the Panama Canal, and around to the Pacific Coast at about one-fourth the cost for sending it across the country by rail. This being the case, Cincinnati's position is strategic, for she is the nearest large city to the center of population, central to the fertile Ohio valley, a very important grain center, and has easy access to the ore deposits of Northern Michigan and the great soft coal regions of the United States. With a clear passage from Pittsburg to the Gulf, river commerce should increase enormously, and Cincinnati's industrial progress should be correspondingly nurtured.

STROPHOMENA AND OTHER FOSSILS FROM CINCINNATIAN AND MOHAWKIAN HORIZONS, CHIEFLY IN OHIO, INDIANA, AND KENTUCKY*

AUG. F. FOERSTE

The Stones River, Black River, and Trenton limestones, in the area crossed by the Cincinnati geanticline, are essentially limestone formations, while the Cincinnatian, including the Richmond, consists of alternations of thin limestones with variable amounts of argillaceous matter. This contrast is emphasized if the Catheys be placed at the base of the Cincinnatian, instead of at the top of the Trenton.

At various periods during the deposition of these strata, argillaceous elements predominated, and during the most important of these, judging from the comparative absence of fossils, life must have been nearly extinct over areas by no means inconsiderable. These periods of local extinction of life, or the withdrawal of life to narrower areas, were followed by others during which life spread and again covered more or less of the area from which it had retreated. In some cases, the returning life came from a source quite different from that to which the former life had retreated, so that a relatively new fauna was introduced into the territory under consideration. Such a change of faunas gives the intervening argillaceous, more or less unfossiliferous strata their chief importance from the standpoint of stratigraphical geology.

One of the most important of these comparatively unfossiliferous sections of argillaceous strata is that to which the name Paint Lick was applied. This forms the lower part of the Garrard formation as originally defined by Marius R. Campbell, the upper part corresponding to the Mount Hope member of the Maysville, stratigraphically. The Paint Lick member of the original Garrard formation may be traced from Bath county south-

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westward as far as Boyle county, in Kentucky. West of this line of outcrop, the Paint Lick member apparently is replaced by more fossiliferous strata, but where it is characteristically developed, the overlying Mount Hope and Fairmount faunas are in striking contrast with the underlying Eden faunas. This contrast is greatest southward, in Madison, Garrard, Lincoln, and Boyle counties, where that part of the Eden below the Paint Lick horizon was grouped under the term Million, on account of its different faunal expression from that exhibited by the Eden at Cincinnati. At Cincinnati, however, where the typical Paint Lick member is absent, the McMicken member bridges, in part, the faunal break.

Moreover, the central and southern Kentucky representatives of the Mount Hope and Fairmount members at Cincinnati belong to the southern or Maury phase of the Fairview division of the Maysville. This is another reason why the contrast between the faunas above and below the Paint Lick horizon appears greatest southward, where the intermingling of faunas was least possible.

Another important, practically unfossiliferous, argillaceous section is that represented by the Tate member, between the Fairview and McMillan divisions of the Maysville. This may be traced all the way from Casey and Boyle counties, in central Kentucky, to Adams county, in Ohio. In this case the greatest contrast between the overlying and underlying faunas again is seen farther southward, in Madison, Garrard, Lincoln, Boyle, and Marion counties, while at Cincinnati the contrast is considerable, but not as striking. Moreover, in the counties of central Kentucky just named, that part of the McMillan section which overlies the Tate member consists chiefly of dove-colored limestone layers, which are in rather striking contrast lithologically with the stratigraphically equivalent strata northward. For this part of the McMillan section, in central Kentucky, the term Gilbert member has been adopted. Stratigraphically it corresponds most nearly to the Corryville member northward.

Another argillaceous horizon forms the lower half of the Arnheim, and has been called the Sunset division of the latter. This horizon can be recognized most readily between Adams county, in Ohio, and Stanford, in Lincoln county, Kentucky. Northward, this lower, or Sunset division of the Arnheim, is moderately fossiliferous, but between the southern margin of Clark county

and Stanford, the lower part of the Arnheim is characterized by an entirely unfossiliferous shaly rock overlaid by a thinner section of dove-colored limestones, and the latter by the richly fossiliferous strata forming the upper part of the Arnheim. In central Kentucky, the Arnheim fauna, overlying the argillaceous Sunset division, is strikingly different from the underlying fauna of the McMillan, while northward, in Ohio and Indiana, the lower Arnheim fauna bridges the gap between the upper Arnheim and the Mount Auburn.

The stretch of territory between Boyle county, in central Kentucky, and Adams county, in Ohio, was an important one in the distribution of faunas, especially during the deposition of the Eden and Maysville. There is abundant evidence that during this time there was free access from the seas southwest of central Kentucky to those northeast of this area, across the region now traversed by the Cincinnati geanticline. Frequently, there is a greater similarity of faunas for many miles from Boyle county northeastward toward Adams county than for a much shorter distance northwestward from this line. This is true especially during the deposition of the lower and upper part of the middle Eden, and also of the Mount Hope and Fairmount. It is illustrated by the early introduction of *Strophomena maysvillensis* along this line, during the Mount Hope, and by the distribution of *Orthorhynchula linneyi*, *Escharopora hilli*, and *Cyrtoceras vallandinghami* during the later part of the Fairmount. The distribution of the Rogers Gap fauna, at the base of the Eden section as exposed in central Kentucky, is chiefly along this channel. Even the typical Mount Auburn fauna, extending northward to Cincinnati and Lebanon, finds a greater extension in Clermont, Brown, and Adams counties in Ohio, and in Lewis, Fleming and Bath counties in Kentucky, than in the western parts of Hamilton and Butler counties, in Ohio, or in any part of Indiana.

The channel across the region later occupied by the Cincinnati geanticline, by way of Casey, Boyle, Lincoln and Garrard counties, was open also during the deposition of the upper part of the Arnheim, as is attested by the distribution of *Platystrophia ponderosa*, *Rhynchotrema dentata*, and to a certain extent by the distribution of *Leptaena richmondensis* during this period. It must have been open also for a brief period at the close of the Waynesville or the beginning of the Liberty, while the *Beatricea* and coral

fauna of Nelson, Washington, Marion, and Casey counties made its way as far eastward as Ophelia, 4 miles north of Richmond, in Madison county, Kentucky.

Another great period of deposition of argillaceous strata occurred during the Waynesville. Here, again, unfossiliferous, argillaceous deposits characterize the lower part of the member, while a return of fossil faunas takes place during the deposition of the upper part. In Marion, Boyle, Casey, Lincoln, Garrard, Madison, and Clark counties, in central Kentucky, no fossils occur in the lower part of the Waynesville, unless a thin, richly fosilliferous strip, often less than 2 feet thick, at the very base of the formation, be regarded as of Waynesville age. As the lower, unfossiliferous part of the Waynesville is traced northward, on the western side of the Cincinnati geanticline, it first becomes moderately fossiliferous, as far as Oldham county. From this point northward the abundance of fossils and the number of species rapidly increases. Similar features are seen on the eastern side of the Cincinnati geanticline, where the fossils are only moderately numerous in the lower part of the Waynesville, in Montgomery and Bath counties, in Kentucky, but become abundant farther northward.

The Fort Ancient and Clarksville divisions of the Waynesville can be traced only a short distance south of the Ohio River, on the eastern side of the geanticline. The Blanchester division, however, has been traced as far as Owingsville, in Bath county. On the western side of the Cincinnati geanticline, the Fort Ancient and Clarksville divisions have not been traced south of Trimble county. The characteristic fossils of the Blanchester division have not been seen south of the northern part of Jefferson county, in Indiana, although the upper part of the Waynesville member, as exposed at Madison, is believed to belong to this division. The Liberty, however, extends far southward, to the vicinity of Raywick, in the western part of Marion county, Kentucky, On the eastern side of the geanticline, the Liberty fauna also may be traced southward beyond the Ohio River, to Owingsville, in Bath county, Kentucky.

From Bullitt county southward, the upper part of the Waynesville or the basal part of the Liberty is characterized by the presence of numerous specimens of *Columnaria, Calapoecia, Tetradium,* and a variable number of specimens of *Beatricea.* This

coral horizon may be traced southward as far as Marion, Boyle, and Casey counties, and eastward to Lincoln, Garrard, and Madison counties. At these more southern localities it forms a thin wedge, only a few feet thick, between the underlying unfossiliferous argillaceous Waynesville strata and the overlying unfossiliferous argillaceous strata which northward merge into the Saluda of southern Indiana.

The Saluda represents another great period of deposition of argillaceous strata. Where it is more typically developed, in Jefferson and Clark counties, in Indiana, and in Trimble, Oldham, Jefferson, and Bullitt counties, in Kentucky, it is nearly or entirely unfossiliferous. This is practically its character also southward, in Nelson, Washington, and Marion counties, although there are local areas within which *Tetradium* and *Stromatocerium* are abundant at the extreme top of the Saluda. A relatively thin fossiliferous layer, the Hitz layer, occurs immediately above the Saluda also between the eastern part of Jefferson county, in Kentucky, and the southern limit of Ripley county.

From the vicinity of Madison, in Indiana, the fossil content of the Saluda, especially of the upper two-thirds, increases gradually northward, but as far as the extreme northern edge of Ripley county there is a band of shaly, unfossiliferous strata in the lower third of the Saluda, which is very characteristic of this horizon. North of Weisburg and Ballstown, in Ripley county, the Saluda has not as yet been traced with care. Owing to the rapidity of the increase of the fossil content on passing northward through Ripley county, and owing to the accompanying lithological changes, it is highly desirable that a more detailed study be made to determine what are the exact stratigraphical equivalents of the different parts of the Saluda north of Ripley county.

For the present, it may be stated that while the lower part of the Waynesville was being deposited in Ohio and Indiana, the south-central part of Kentucky was practically devoid of life. Only the upper part of the typical Waynesville fauna reached Jefferson county, in Kentucky, and only the lower part of the Liberty reached Marion county, unless the great coral horizon is to be regarded as belonging to the top of the Waynesville. Before the invading argillaceous deposits of the Saluda, the Liberty fauna retreated northward to the Ohio and Indiana basin, from

which the Waynesville invasion formerly had progressed southward.

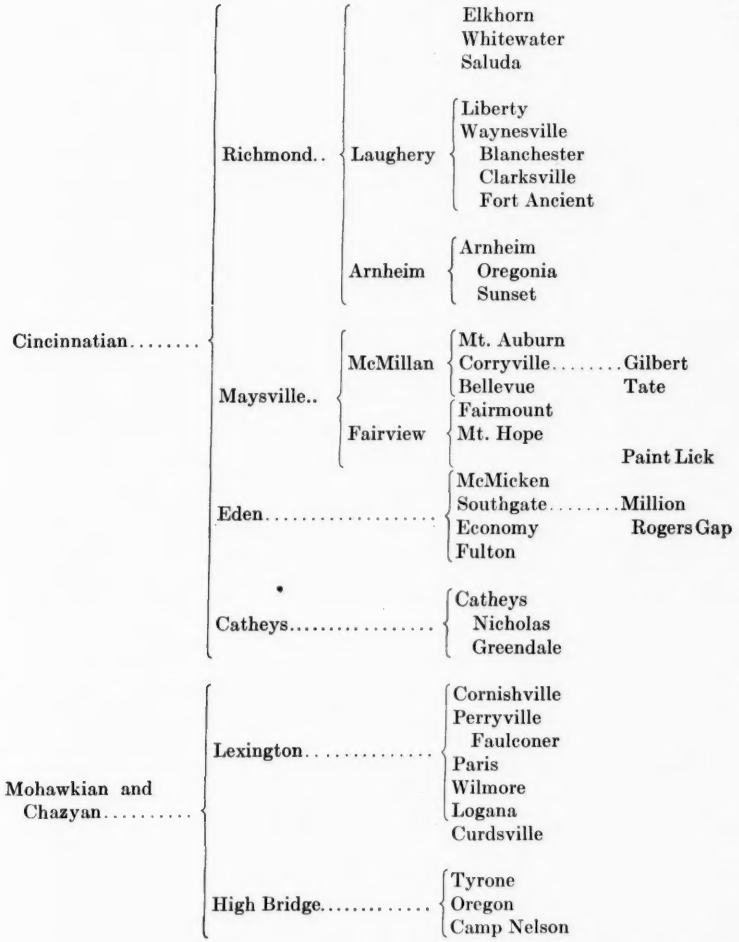
The Waynesville and Liberty, taken together, contain that part of the Richmond fauna along the Cincinnati geanticline which most nearly is related to the Mississippi Valley Richmond. The two formations appear more closely linked together in their fossil content than the other Richmond formations. For that reason the term Laughery formation is proposed for the Waynesville and Liberty as exposed along Laughery Creek in Ripley county, Indiana.

On the eastern side of the Cincinnati geanticline, the Blanchester division of the Waynesville bed may be traced by means of typical fossils as far as Owingsville, in Bath county, and the base of the Liberty is fossiliferous as far as the same locality. Here again it is the strata along the plane of junction between the Waynesville and Liberty which may be traced farthest southward.

The great coral horizon at the top of the Waynesville or at the base of the Liberty may be traced from the western side of the Cincinnati geanticline eastward as far as Ophelia, 4 miles north of Richmond, in Madison county, and as far as the mouth of the Red River at the northeastern edge of this county. Here it may be seen that the overlying strata are unfossiliferous southward, but gradually become more and more fossiliferous northward, simulating in this respect the features shown by the Saluda on the western side of the geanticline.

Owing to the considerable lithological and accompanying faunal differences between the Cincinnatian strata as exposed in Ohio and Indiana, and their approximate stratigraphical equivalents in central Kentucky, it may prove convenient, locally, to recognize only the greater subdivisions of the Cincinnatian strata, as proposed at the typical section, at Cincinnati, Ohio, and to adopt a somewhat different set of subdivisions southward.

The terms employed on the following pages are indicated in the following table.


Cincinnatian
Richmond
Laughery
Elkhorn
Whitewater
Saluda
Liberty
Waynesville
Blanchester
Clarksville
Fort Ancient
Arnheim
Arnheim
Oregonia
Sunset
Maysville
McMillan
Mt. Auburn
Corryville
Gilbert
Bellevue
Tate
Fairview
Fairmount
Mt. Hope
Paint Lick
Eden
McMicken
Southgate
Million
Economy
Rogers Gap
Fulton
Catheys
Catheys
Nicholas
Greendale
Mohawkian and Chazyan
Lexington
Cornishville
Perryville
Faulconer
Paris
Wilmore
Logana
Curdsville
High Bridge
Tyrone
Oregon
Camp Nelson

Strophomena incurvata, Shepard[1]

XI

(Plate XI, Figs. 7, 9 A, B, C)

Brachial valve usually moderately convex, valves 40 mm. in diameter, having a convexity of 7 to 10 mm. Pedicel valve moderately concave, the concavity varying from 3 to 5 mm. in shells 40 mm. in width. Postero-lateral angles usually varying between 75 and 85 degrees, although occasionally the shell is sufficiently extended along the hinge-line to produce an angle of 60 degrees. The more quadratic forms are more common. In the specimens from Cloche Island, the shell frequently is wrinkled along the hinge-line. Usually these wrinkles are strongly oblique, making angles of 25 to 30 degrees with the hinge-line, although occasionally the angles are as low as 15 degrees, and still more rarely some of the wrinkles nearest the postero-lateral angles form angles as high as 60 degrees, resembling the more vertical wrinkles seen in *Strophomena vetusta*. Radiating striae on the brachial valve, usually about 7 or 8 in a width of 2 mm., where there is no intercalation of additional striae. In those parts of the shell where numerous additional striae have been intercalated a short distance posteriorly, the number of radiating striae may reach 12 in a width of 2 mm. Striae usually subequal, or alternating in size. Occasionally, every fourth striation is more conspicuous, being stronger and more elevated. Striations transverse to the radiating striae, very fine. No evidence of concentric wrinkling.

Hinge area on pedicel valve with a height of 3.5 mm. in specimens 40 mm. in width; decreasing in height slowly until near the postero-lateral angles. Margins of the delthyrium forming an angle of about 80 degrees. Deltidium low, frequently with the sides flattened so as to produce a more angular median line than is usual in other species of *Strophomena*. This angularity is best exhibited in the specimens from Cloche Island, but it is seen also in some of the Kentucky specimens. The more evenly convex deltidia also occur. The divergent sides of the deltidium extend diagonally forward from the median line for a distance of 5 or 6 mm.; their distal terminations forming the dental plates. The latter extend from 1 to $1\frac{1}{2}$ mm. beyond the anterior margin of

[1] *American Jour. Sci.*, vol. xxxiv, p. 144, 1838.

the hinge-area, and coalesce with the lateral, sharply raised border of the muscular area. This muscular area varies from rounded rhomboidal, to nearly circular in outline. The muscular area rises rather gradually toward its antero-lateral borders, but the slope from these borders toward the body cavity is abrupt. The chief characteristic of the muscular area is the presence of eight to ten rather indistinct radiating striae within the area of each of the diductor scars, separated by a low median elevation. This is the flabellate type of scar, in which the anterior and posterior divisions of the diductor scars are not distinctly differentiated. The entire interior of the body cavity, outside of the muscular area, is minutely granulose. In the case of very thin valves, in which the radiating striae ornamenting its exterior may be readily detected also on the interior surface, these granules are arranged along lines corresponding to the grooves between the exterior striae, but on the ordinary, thicker valves, these granules are arranged more irregularly.

The antero-lateral raised borders of the muscular area, in case of the pedicel valve, approach anteriorly within about 3 mm. of each other and then curve sharply backward toward the lateral margins of the low median elevation which traverses the area from front to rear. This leaves an anterior gap, which is very characteristic of all species of *Strophomena*. The muscular area is surrounded on all sides, except at the gap, by a series of short ridges, arranged with their axes parallel to the radiating lines. These short ridges sometimes merge into longer, straight ridges, especially posteriorly, toward the hinge-area, but usually they are discrete. On each side of the gap, these short ridges cover an area extending about 2 mm. anterior to the raised border of the muscular area. Laterally, these ridges cover an area extending from 4 to 5 mm. from the lateral border of the muscular area, and they occupy the space directly posterior to that just described, as far as the hinge-area.

The interior of the pedicel valve is thickened within a short distance of the anterior and lateral margins. Anteriorly, the maximum thickening is about 4 or 5 mm. from the edge of the shell. Laterally, this thickening becomes less pronounced, and the maximum thickening approaches to within 2 mm. of the lateral margin, near the hinge-area. Occasionally this thickening equals fully $1\frac{1}{2}$ mm. anteriorly, but usually it is less than 1 mm., and may

be quite inconspicuous. This thickened region is crossed radially by rather distant grooves which may be traced posteriorly for a short distance, sometimes about half the distance from the thickened region to the muscular area. Toward the margin of the valve, these grooves frequently branch several times.

Excepting within the region of the muscular area, the interior of the brachial valve is minutely granulose, with indications of short radial ridges corresponding in position to those already described in case of the pedicel valve. A low elevation extends from front to rear across the muscular area. Two low but rather narrow and sharp ridges, 6 to 7 mm. long, and 5 mm. apart, extend across the middle of the valve, in a direction from front to rear. These ridges correspond to the outer pair of the four ridges limiting the median vascular sinuses in such species as *Strophomena vetusta*. The anterior and posterior adductor scars are rather indistinctly defined. The cardinal process is bifid, the two lobes being divergent; the posterior faces of these lobes are crossed by a groove. The crural plates are strongly divergent, and become subparallel to the hinge-area within 1½ mm. of the latter.

Strophomena incurvata was described by Shepard from the vicinity of Green Bay, Wisconsin, where it occurs in strata regarded as equivalent to the Black River formations.

In the lower part of the equivalent strata of Minnesota, *Strophomena incurvata* is associated with *Rafinesquina minnesotensis, Orthis tricenaria, Dinorthis deflecta, Hebertella bellarugosa, Dalmanella subaequata* with several of its varieties, and *Rhynchotrema inaequivalve*. All of these species, with the exception of *Dinorthis deflecta*, are represented also in the upper part of the Black River section of Minnesota, either by typical specimens or by varieties of the species. *Dinorthis pectinella* is listed only from the upper part of the Black River in Minnesota.

The association of *Strophomena incurvata* with *Orthis tricenaria, Dinorthis pectinella*, and *Hebertella bellarugosa* is found on Cloche Island, northeast of Little Current, west of Georgian Bay, in Ontario. South of Cloche Island, on the northeastern edge of Goat Island, *Strophomena incurvata* is associated with *Orthis tricenaria, Dinorthis pectinella*, and species of *Carabocrinus* and *Cleiocrinus*. These are typical Black River exposures.

In central Kentucky, the large typical specimens of *Orthis tricenaria* and *Dinorthis pectinella*, associated with *Carabocrinus*

and *Cleiocrinus*, occur in the Curdsville bed. *Hebertella bellarugosa* is absent at this horizon. I have never found any species of *Strophomena* at this horizon, but Mr. E. O. Ulrich listed *Strophomena filitexta* ("Correlation of the Lower Silurian," *Am. Geol.*, vol. i, p. 108, 1888), a species now included under *Strophomena incurvata*, from the Curdsville. If the Curdsville member finds any approximate equivalent in the Ordovician section along the northern part of Lake Huron, it must be in the upper part of the Black River section, as exposed on Goat Island. There are sufficient differences in the faunas, however, to make exact equivalency uncertain.

The most typical specimens of *Strophomena incurvata* in central Kentucky are found in the Tyrone member. At High Bridge, between 24 and 29 feet below the clay at the top of this member, there is a richly fossiliferous horizon at which *Strophomena incurvata* is abundant. Here it is associated with *Rafinesquina minnesotensis*, and small specimens referred to *Orthis tricenaria*. I have never found *Dalmanella subaequata*, *Dinorthis deflecta*, or *Hebertella bellarugosa* at this horizon, although Mr. Ulrich lists the first two species from the richly fossiliferous horizon here under consideration, and the last species from the upper, cherty part of the Tyrone. The Oregon member contains very few fossils; no species of *Strophomena* has been found.

Specimens of *Strophomena* closely resembling *Strophomena incurvata* occur at several horizons in the Camp Nelson member of the Stones River group; the only ones recorded were from 35 and 95 feet below the top of this member. The lower part of this division, as exposed near Camp Nelson, Kentucky, has not been studied. At High Bridge, *Rafinesquina minnesotensis*, *Orthis tricenaria*, *Hebertella bellarugosa*, and *Rhynchotrema inaequivalve* have been collected between 130 and 140 feet below the top of this division. *Dinorthis deflecta* and *Dalmanella subaequata* are known from 120 feet below the top. Judging from the published lists of fossils from the equivalent strata in southern Tennessee ("Columbia folio," U. S. Geol. Surv., Hayes and Ulrich, 1903), the Camp Nelson member corresponds to the Lebanon and Ridley members of the Stones River group. Apparently most of the exposed part of the Camp Nelson member, at High Bridge, belongs to the Lebanon member. In Tennessee,

Strophomena incurvata is listed also from the Pierce division of the Stones River group.

Strata closely resembling the very fine-grained limestones characterizing the High Bridge limestone in central Kentucky, occur also in Ontario, along the northern part of Cloche Island, along the railroad track, below undoubted Black River strata. In the absence of fossils, however, their exact equivalency to Kentucky or Tennessee strata must remain for future determination, although for the present they are regarded as of Lowville age.

Strophomena incurvata makes its first appearance in the Pierce limestone of Tennessee. Thence it ranges upward to the base of the Carters limestone. Since the lower divisions of the Stones River group are not known from the northern part of the Mississippi basin or from the region bordering the Great Lakes, this evidence favors the introduction of *Strophomena incurvata* from some other direction, probably the south or southeast, although during late Stones River times and during the deposition of the Black River, this species spread to Iowa, Wisconsin, Minnesota, Manitoba, and the northern parts of Lake Huron. During the deposition of the Black River, it even reached New York and Canada.

The finely striated species of *Strophomena*, with flabellate muscular scars in the pedicel valve, typified by *Strophomena incurvata*, are unknown, in the areas traversed by the Cincinnati geanticline, in the Trenton, Eden, and Maysville formations, but return in the form of *Strophomena neglecta* and *Strophomena planodorsata* in the Waynesville and closely related horizons of the Richmond. *Strophomena planodorsata* replaces *Strophomena neglecta* northwestward, in Minnesota and neighboring states, and extends southward to western Tennessee.

Strophomena vicina, Foerste[2]

(Plate VII, Fig. 2, magnified)

Shells varying from 30 to 35 mm. in width along the hinge-line, occasionally attaining a width of 40 mm. The ratio of the width to the length usually varies from six-tenths to seven-tenths.

[2] *Denison Univ. Bull.*, vol. xiv, p. 317, Plate VII, Figs. 12 *A*, *B*, 1909.

Postero-lateral angles varying from 70 to 85 degrees, giving rise to two types of outline, in one of which the postero-lateral angles vary from 70 to 75 degrees, and the shell is broadly and transversely semi-elliptical. In the other type of shell, the postero-lateral angles equal about 85 degrees, and the outline is subquadratic. Apparently the shells with the more acute postero-lateral angles are less convex, while the convexity of the more quadratic forms is greater. This convexity usually equals 4 or 5 mm. in the former group and 6 or 7 mm. in the latter. The brachial valves are evenly convex from front to rear, with a scarcely perceptible depression about a millimeter from the beak. The concavity of the pedicel valve varies from 1 to 2 mm. Oblique wrinkling of the shell along the hinge-line is rare, and not at all characteristic of the species. In one specimen these wrinkles formed an angle of about 40 degrees with the hinge-line. The number of radiating striae usually equals 6 or 7 in a width of 2 mm., but may be as low as 5, and as high as 9 or 10, in the case of individual specimens.

Deltidium of the pedicel valve broadly convex, the teeth extending only a short distance, usually less than a millimeter, beyond the hinge-area. Muscular area rounded, subrhomboidal, with a strongly raised lateral border posteriorly, becoming less conspicuous anteriorly, where it is deflected toward the front, leaving a gap varying from 2 to 3 mm. in width. The muscular area is traversed by a low, broad, median elevation, bearing indications of the attachment of the adductor muscles posteriorly. There is a tendency toward a linear depression on each side of this median elevation, extending forward through the gap. The area of attachment of the diductor muscles frequently is divided by a more or less distinct ridge into two parts, of which the one nearest the postero-lateral border is the narrowest. There are no radiating striae of about equal size and even distribution as in the case of *Strophomena incurvata*. The type of muscular area seen in *Strophomena vicina* is that typified by *Strophomena planumbona*, of which it may be regarded as a precursor. The interior of the body cavity is comparatively smooth. There is a slight thickening of the valve about 4 mm. from the anterior margin, this thickening usually equalling less than a millimeter. It is crossed by vascular grooves, branching anteriorly and merging along the margin into the numerous grooves corresponding, in position, to the radiating striae on the exterior of the shell.

In the case of one brachial valve, the inner margins of the two lobes of the cardinal process are almost in contact with each other, forming subparallel ridges along the posterior faces of the lobes. Broad and shallow grooves separate these ridges from the postero-lateral margins of the lobes, which practically are in contact with the crural ridges. These features may not be characteristic of the species. In another specimen there is a broad median elevation separating two obovate muscular scars, which posteriorly are traversed by short, moderately radiating lines, and anteriorly give rise to the two outer, and more conspicuous subparallel ridges of the group of four which limit the median vascular sinuses in the genus *Strophomena*.

The type specimens were collected on the farm of C. H. Bowyer, half a mile northeast of Becknerville, in Clark county, Kentucky. Specimens occur also at several localities from a mile to a mile and a half northwest of Becknerville, on the road to Pine Grove. The station labelled Pine Grove on the Richmond sheet of the United States Geological Survey, at present is named Colby. Near Becknerville, *Strophomena vicina* is associated with *Dinorthis ulrichi*, *Hebertella frankfortensis*, and *Rhynchotrema inaequivalve*. The same horizon is exposed at Flanagan. Here the following section is exposed in descending order. The rock is limestone. Only the ranges of the included fossils are indicated.

Numerous specimens of *Allonychia flanaganensis*, 11 cm. in length from the beak along the umbonal ridge, hinge area 6.5 cm. in length extending 5 to 8 mm. anterior to the tip of the beak, hinge area 4 to 6 mm. high, shell surface apparently smooth.
Granular limestone ..... 11 ft.
Granular limestone, one large *Hebertella frankfortensis* ..... 5 ft. 6 in.
Road crossing, a mile and a half northeast of Flanagan.
Granular limestone with *Rhynchotrema inaequivalve* ..... 5 ft. 6 in.
Road crossing.
Granular limestone northward, clayey with abundant chert fragments southward ..... 3 ft. 6 in.
Chiefly weathered to clay, with argillaceous, fine-grained rock masses remaining in places. At this and the immediately overlying horizon, the typical Flanagan chert makes its appearance ..... 5 ft. 6 in.
Road crossing.
Strophomena, very thin, finely-striated specimens which may not belong to *Strophomena vicina*. Also a variety of *Rhynchotrema inaequivalve* ..... 6 in.

Numerous bryozoans and a few *Rhynchotrema*.....5 ft.
Strophomena vicina fairly common in a coarse-grained limestone..1 ft. 6 in.
Dinorthis ulrichi, Rhynchotrema inaequivalve, and *Hebertella frankfortensis* range throughout this section. *Strophomena vicina* occurs only within one foot of the top.....6 ft.
Interval.....1 ft.
Crossing of farm road over railroad.
Interval.....2 ft. 6 in.
Short railroad bridge, No. 31.
Loose cherty specimens of *Dinorthis ulrichi* and *Rhynchotrema* near the top and *Dalmanella* at the base.....5 ft. 6 in.
One *Strophomena vicina* and *Rhynchotrema* in place.....2 ft.
Rhynchotrema and *Herbertella frankfortensis*.....9 ft.
Flanagan railroad station.

This section undoubtedly belongs to the upper part of the Lexington limestone, probably the Paris bed. The nearest known outcrop of the Perryville bed is 28 miles southwestward, at Toddville, in Garrard county, and it is not known at present whether the Perryville bed and the overlying Cornishville bed may be traced beyond Toddville, northward; hence a more exact correlation is impossible. An interesting feature of the section along the railroad north of Flanagan is that it suggests the presence of *Strophomena* at a horizon 15 feet lower than that at which it is associated with *Dinorthis ulrichi.* Going northward along the railroad, *Hebertella frankfortensis* and *Rhynchotrema inaequivalve* occur at still higher levels, but the possibility of faulting can not be excluded.

It should be noted that at Flanagan, the Flanagan chert belongs immediately above the *Strophomena vicina* and *Dinorthis ulrichi* horizon. This is true also 4 miles northwest of Flanagan, at the northern edge of the C. H. Bowyer farm, nearly a mile north of Becknerville.

Strophomena vicina, associated with *Dinorthis ulrichi* and *Rhynchotrema inaequivalve,* occurs in the upper part of the Lexington limestone also, in the western edge of Valley View, halfway between Flanagan and Toddville. Twenty miles northwest of Flanagan, the same association of fossils, including also *Hebertella frankfortensis,* occurs at the G. C. Gorham quarry, 4 miles northeast of Lexington, on the Newtown pike. Less than 9 miles northwest of the last locality, half a mile west of Georgetown, on the Franklin pike, *Strophomena vicina* and *Dinorthis ulrichi* are found associated, but both are very rare.

In Boyle county, and in the southern half of Mercer county, in Kentucky, the top of the Lexington limestone is formed by a rather coarse-grained, more or less cross-bedded, gray limestone, 4 or 5 feet in thickness, overlying a fine-grained limestone section, about 20 feet thick. The fine-grained limestone forms the Perryville member of the Lexington limestone. The upper part of the Perryville member, varying from 5 to 8 feet in thickness, is very hard, breaks with a splintery fracture, has a dove color, and frequently is marked with little whitish spots, which caused W. M. Linney to apply the term Upper Birdseye Beds to this part of the Lexington section. Westward at Perryville, Nevada, and Cornishville the underlying part of the Perryville bed is darker, softer, and much more richly fossiliferous. In fact, it is the richest fossil horizon in the Lexington section. Eastward, at Danville, a mile and a half northwest of Faulconer, and near Harrodsburg, this lower part of the Perryville section is whiter and even more richly fossiliferous. It contains the fauna described by Ulrich from the vicinity of Danville and Burgin and forms the Faulconer division of the Perryville.

The coarse-grained limestone, overlying the Perryville member, may be called the Cornishville limestone, from the village in Mercer county, 11 miles north of Perryville. It contains *Strophomena vicina, Dinorthis ulrichi, Hebertella frankfortensis, Platystrophia colbiensis, Rhynchotrema inaequivalve,* and *Stromatocerium canadense. Strophomena vicina* occurs in the Cornishville limestone at Cornishville, 9 miles west of Harrodsburg; at the railroad crossing, 2 miles northwest of Harrodsburg; at several localities along the railroad southeast of Harrodsburg, as far as the county line; and 2 miles east of Harrodsburg; all in Mercer county. In Boyle county, it occurs at several localities within 3 miles southeast of Perryville, and between Perryville and Atoka.

The Perryville bed may be identified 11 miles northeast of McAfee, on the farm of Mrs. Ben Williams, 2 miles south of the Crow distillery at Glenn Creek Station. Here the more typical part of the Perryville section is 7 feet thick. The rock resembles the darker, fine-grained limestone forming the lower part of the Perryville section at Cornishville, and contains *Isochilina jonesi, Loxoceras milleri,* and other fossils. The immediately underlying whitish siliceous limestone, 6 feet thick and full of gasteropod

remains, also may belong to that part of the Perryville section, which between Harrodsburg and Danville is characterized by the abundance of silicified gasteropod remains. The Cornishville limestone has not been identified here.

About 9 miles northeast of the last locality, 4 miles north of Versailles, along a road reached by going from Wallace a little over a mile westward and then a mile and a half southward, the Perryville bed is represented by residual boulders of a very white, dense limestone containing *Orthorhynchula linneyi*, *Oxydiscus subacutus*, *Isochilina jonesi*, and a species of *Tetradium*. This rock resembles the very white rock at the top of the Perryville bed, but similar rock, full of silicified fossils, occurs in the lower part of the Perryville bed, between Harrodsburg and Danville. The gasteropod layer also is represented, in this area, southwest of Wallace, by large boulders. Similar boulders occur 2 miles southeast of Wallace, near the Mount Vernon pike, and 1 mile northeast of Versailles, along the railroad.

Seven miles north of Versailles, three-quarters of a mile southeast of Ducker Station, the siliceous gasteropod layer varies from 4 to 6½ feet thick. It is overlaid by very white, fine-grained limestone containing specimens of *Leperditia*, evidently belonging to the Perryville bed. This limestone is only 1 foot thick, and is overlaid by a foot and a half of nodular argillaceous limestone, which may belong to the same horizon.

The very white limestone characterizing the upper part of the Perryville bed is seen also southwest of Frankfort, opposite the western entrance to the Taylor grounds. Loose fragments resembling the gasteropod layer are seen. These outliers of the Perryville limestone suggest an unconformity between the Lexington and Winchester limestones. Moreover, the gasteropod layer, if it represents the lower part of the Perryville bed, suggests an overlap of the Perryville on the Paris bed, thinning out northeastward. This will account for an absence of any trace of the Perryville bed northeast of a line connecting Frankfort and Toddville. Hence it is not believed possible to correlate the lower, richly fossiliferous part of the Perryville bed, full of gasteropods, with the Flanagan chert of the Richmond folio.

The upper part of the Paris bed, in Woodford, and Franklin counties, is a rather coarse-grained, often cross-bedded, and more or less phosphatic limestone. This is underlaid by a more fossil-

iferous section, and about 55 feet below the top of the Paris bed there is a layer of rather fine-grained argillaceous limestone, about 10 feet thick, in which *Strophomena vicina* occurs, associated with *Platystrophia colbiensis*. This *Strophomena vicina* horizon, which is distinctly below the top of the Paris bed, may be traced from Glenn Creek and Frankfort westward to Bridgeport and Benson.

Eastward, this lower *Strophomena vicina* horizon may be traced to Versailles; 5½ miles northwest of Versailles, a mile and a half west of McKee Stop on the Frankfort traction; nearly 2 miles northwest of Midway; also 3½ miles south of Versailles, on the road to Pinckard.

The argillaceous, fine-grained limestone, characteristic of this lower *Strophomena vicina* horizon westward, can not be traced beyond Versailles, but the *Strophomena vicina* horizon maintains the same relative position in the Paris bed as far east at least as Brannon, in the north-central part of Jessamine county, and the western part of Fayette. Sometimes *Strophomena vicina* occurs not in the fine-grained limestone layer already discussed, but immediately beneath. Not infrequently *Stromatocerium canadense* occurs immediately above the *Strophomena vicina* horizon. It occurs in this association about 3 miles southwest of Frankfort, east of the home of B. B. Graves on the Lawrenceburg pike; south of Glenn Creek; 3½ miles south of Versailles, on the road to Pinckard; at several localities near Brannon; and at the Gorham quarry, 4 miles northeast of Lexington, on the Newtown pike. At the first and last of these localities, *Strophomena vicina* is associated with *Dinorthis ulrichi*, which suggests that this fossil also occurs at two horizons: in the Cornishville limestone and also about 50 or 60 feet below the top of the Paris bed. So far, *Strophomena vicina* has not been found below the lower one of these horizons.

At the depot, at Lair Station, in the southern part of Harrison county, *Strophomena vicina* occurs in the Paris bed, 18 feet below the top of the Lexington limestone. The upper part of the Lexington limestone here is almost unfossiliferous. Half a mile west of Pine Grove, in the western edge of Clark county, it occurs in an argillaceous rock, probably belonging at least 20 feet below the top of the Lexington limestone, but its horizon is not definitely known. At Cynthiana, it occurs in the upper part of the quarried rock, also referred to the Paris bed.

One of the most interesting occurrences of *Strophomena vicina* is at Carnestown, in Pendleton county, on the Ohio River, in strata associated with *Eridotrypa mutabilis, Eridotrypa trentonensis, Prasopora falesi, Prasopora simulatrix, Callopora multitabulata, Dalmanella bassleri, Platystrophia colbiensis, Plectambonites sericea,* and *Zygospira recurvirostra.* At Frankfort, *Callopora multitabulata* ranges up as far as the *Strophomena* horizon. *Prasopora simulatrix,* from the Wilmore, gives rise to a closely similar form which reaches the same *Strophomena* horizon, and *Eridotrypa mutabilis* certainly occurs in the lower part of the Paris bed. As far as the present evidence warrants any conclusion, there is no necessity of regarding the *Strophomena vicina* horizon at Carnestown as below the base of the Paris bed.

Thin specimens of *Strophomena,* similar to those at the top of the section described from the vicinity of Flanagan, occur in the upper part of the Paris bed, 2 miles southeast of Brennan Springs, in the northeastern part of Henry county.

Strophomena trentonensis was described by Schuchert from the upper part of the Decorah and the lower part of the Prosser in Minnesota. This is distinctly below the level of the Paris or Bigby bed, in Kentucky. The striae are described as more delicate than those of *Strophomena planumbona-subtenta,* and the oblique wrinkling along the cardinal margin is said to be a more constant feature than in that species. Neither of these statements is true of *Strophomena vicina.* There can be no doubt, however, of the close relationship between these two forms.

No species of *Strophomena* is listed from the Bigby included within the area covered by the Columbia folio, but the *Strophomena* recorded by Schuchert as occurring near the top of the Trenton near Nashville, Tennessee, may be *Strophomena vicina,* rather than *Strophomena trentonensis.* No species of *Strophomena* is known from any part of the Wilmore or Logana (Hermitage of Ulrich).

As far as the origin of *Strophomena vicina* is concerned, it was introduced into central Kentucky during the deposition of the argillaceous limestone 55 feet below the top of the Paris or Bigby bed. This argillaceous horizon is best developed on the western side of the Cincinnati geanticline, in Franklin, Woodford,

and Anderson counties, and here *Strophomena vicina* is most abundant, although it occurs at corresponding horizons also farther eastward. It reappears at the top of the Lexington limestone, in the Cornishville member, in Mercer and Boyle counties. Both the Cornishville member and the underlying Perryville member thin out northeastward, so that their faunas may be regarded as of western or southwestern introduction, as far as this part of the evidence is concerned.

In the Cornishville member, *Strophomena vicina* is associated with numerous specimens of *Dinorthis ulrichi*, and specimens of *Dinorthis ulrichi* occur also locally at the lower *Strophomena vicina* horizon, near the base of the Paris member. Both species probably entered the areas traversed by the Cincinnati geanticline from the same source The nearest relatives of *Dinorthis ulrichi* are *Dinorthis meedsi* and its variety *germana*, from the lower part of the Prosser in Minnesota, Iowa, and Wisconsin. Both in Kentucky and in Minnesota these species are associated with *Hebertella frankfortensis*, a very common species of the Paris and Cornishville members of Kentucky, and of the Bigby of Tennessee. Moreover, in Minnesota, *Strophomena trentonensis*, *Hebertella frankfortensis*, and *Dinorthis meedsi-germana* are associated in the *Nematopora* bed, although *Strophomena trentonensis* is listed chiefly from the *Clitambonites* bed, at the base of the Trenton, and in the immediately underlying part of the Black River group. From these data it may be assumed that *Strophomena vicina*, *Dinorthis ulrichi*, and *Hebertella frankfortensis* entered Minnesota, Kentucky, and Tennessee from the same source and that this source lay west of the Cincinnati geanticline. The apparent absence of any relative of *Strophomena vicina* or of *Dinorthis ulrichi* at corresponding horizons within the area covered by the Columbia folio, suggests a northwestern, rather than southwestern origin for these species, although it is acknowledged that the argument is based upon insufficient data.

Of much more interest is the suggestion that, whatever the origin of *Strophomena vicina*, it probably was different from that of *Strophomena incurvata*. *Strophomena vicina* belongs to the *Strophomena planumbona* type of shell, in which the striations are still fine, although usually coarser than in *Strophomena incurvata*, while the muscular area of the pedicel valve is not flabellate but has the anterior prolongation or gap. This type of shell dis-

appears with the close of the Lexington limestone, and is not seen again until the close of the Arnheim, where it is represented by *Strophomena concordensis*. In the Waynesville and Liberty beds, it is represented by *Strophomena planumbona* and its many varieties; and *Strophomena vetusta*, from the Liberty and Whitewater beds, probably is a variation from the same phylum.

Strophomena higginsportensis, sp. nov.

(Plate II, Figs. 3 A, B; Plate X, Fig. 4)

Only the interior of three pedicel valves is known. From these interiors it is evident that the exterior of the pedicel valve is comparatively flat. There is a moderate convexity toward the beak, but anteriorly and laterally the valve is flat rather than concave. The generic relations of the valves is indicated by the muscular area and the hinge-area. In one of the valves from Stony Point, on the Ohio River, in Bracken county, east of Higginsport, the hinge-area has a height of almost 2 mm., the width of the valve being 30 mm. and the length 20 mm. The sides of the delthyrium diverge at an angle of 85 degrees. The deltidium is convex, and the teeth extend scarcely a millimeter beyond the hinge-line. They are supported by flat, vertical, thin dental plates, which extend diagonally forward in the same direction as the sides of the delthyrium, decreasing in height rapidly from the anterior termination of the teeth to a point about $2\frac{1}{2}$ mm. beyond the edge of the hinge-area, defining the posterior parts of the muscular area. From the anterior termination of these dental plates a very low ridge extends forward, limiting the sides of the muscular area. The two ridges are scarcely 3 mm. long; they are slightly convergent toward the front, and at a distance of 5 mm. from the hinge-area, measured vertically, they become imperceptible. The greatest width of the hinge-area is scarcely 6 mm. Anteriorly, the limits of the area are not defined. Excepting in the immediate vicinity of the muscular area, where the shell is smooth, the interior is radiately striated, the shell substance being very thin and plainly indicating the striation on the exterior surface. There are about 15 striae in a width of 5 mm., varying in a second specimen to 19 in a width of 5 mm. A specimen from Ivor, Kentucky, 30 mm. wide and 20 mm. long, presents 12 radiating striae in the same width.

None of these specimens was found in place. The two specimens collected at Stony Point, east of Higginsport, were obtained just above the level of the railroad, among débris regarded at the time of collecting as of lower Eden, or Economy age. The specimen from Ivor, in Pendleton county, was found in the quarry a quarter of a mile east of the railroad station, and evidently had fallen from some ledge exposed in the upper part of the quarry wall. Since both the Winchester or Cynthiana formation, and the lower part of the Eden are exposed here, the exact horizon must remain in doubt.

The danger of founding a new species on the interiors of three ventral valves of a species of *Strophomena* are too obvious to require comment. The possibility of these specimens belonging to the widely spread species of the Eden, *Strophomena hallie*, must be taken into account. Contrasted with the latter species, the following differences are noted. The outline of the shell in *Strophomena hallie* is distinctly more triangular. The brachial valves are strongly convex, and hence the pedicel valve always is distinctly, although not necessarily strongly concave. Compared with the width, the shell is relatively longer. The muscular area is more circular in outline, and is relatively broader. The sides of the delthyrium are more divergent, forming an angle of about 100 degrees. The surface striae are coarser. Usually the specimens of *Strophomena hallie* also are distinctly smaller, equalling about 22 to 25 mm. in width, but one large valve from the lower Eden 1 mile west of Foster, in Bracken county, Kentucky, triangular in form, and referred to this species, measures 37 mm. in width, 27 mm. in length, and has a round muscular area 9 mm. wide.

Strophomena hallie, Miller[3]

(Plate II, Figs. 1 A, B, C, D, E; 2)

Strophomena hallie was described by S. A. Miller from Cincinnati, Ohio. The types were found about 150 feet above low water mark on the Ohio River, in an excavation made for Columbia Avenue. This places their horizon in the Southgate or middle Eden bed. The types are preserved in the Faber collection, in the Walker Museum at Chicago University. They are numbered

[3] *Cincinnati Quarterly Journal of Science*, vol. 1, p. 148, 1874.

8848, and form the originals of Figs. 14, 15 and 16, accompanying the original description. These types are illustrated also by Figs. 1 *A*, *B*, *C* on Plate II of this Bulletin.

The specific name was given as a compliment to Miss Hallie Cotton, who was the first woman to join the Cincinnati Society of Natural History. This name was changed to *hallana* to Latinize the term, but *halliena* would be better if the term be intended as a compliment to Miss Hallie, and not Miss Hall.

The shell is rather small, and subtriangular in outline. The larger specimens equal 23 mm. in length, 27 mm. in width, and about 7 mm. in convexity. They usually do not exceed 30 mm. in width, but occasionally attain a width of 35 mm. Postero-lateral angles frequently rounded, but usually rectangular, and occasionally even moderately acute.

The brachial valve is slightly flattened posteriorly, the concavity immediately anterior to the beak being almost imperceptible. Usually this flattened area does not extend farther than 5 to 7 mm. from the beak. From this area the shell curves rapidly downward toward the antero-lateral margins, frequently producing long flattened slopes in this direction, resulting in a sub-triangular appearance of the shell. The greatest convexity lies along the median part of the valve, about as far back as the middle of the shell. While the subtriangular outline predominates largely, some specimens occur in which the form is more nearly semicircular. In these the brachial valve is more evenly convex.

Pedicel valve moderately but distinctly convex immediately anterior to the beak, with a reversal of curvature toward the middle. The concavity of the pedicel valve usually is small, resulting in a rather plano-convex shell.

The hinge-area of the pedicel valve has a height of scarcely 2 mm. at the beak, diminishing gradually toward the extremities. Sides of the delthyrium forming an angle of about 100 degrees, and the deltidium is convex, but, judging from the specimens at hand, does not fill up as much of the delthyrium as in other species, the chilidium of the brachial valve being more fully developed. Muscular area approximately circular, bordered posteriorly by the teeth, which project only a short distance beyond the hinge-area. From the anterior margin of the dental plates, low curved ridges extend forward, becoming obsolete immediately in front of the area. A narrow median ridge traverses the muscular

area, and serves as a line of attachment for the adductor muscles. Occasionally a parallel ridge traverses this area, on each side of the median one. These lateral ridges correspond to the posterior terminations of the two inner vascular ridges of other species of *Strophomena*. The remainder of the inner surface of the pedicel valve, outside of the muscular area, appears radiately striated, owing to the thinness of the shell permitting the striation of the exterior surface to be seen.

The lobes of the cardinal process of the brachial valve are narrow and small. The extremities of the crural plates frequently deviate but little from the hinge-line. The adductor scars are not well defined laterally or anteriorly. The median ridge extending forward from the cardinal process frequently is bi-lobed at a point almost on a line with the region where the margin of the adductor scars should be. A parallel ridge occasionally is found on each side of this median one. The remainder of the interior is radiately striated on account of the thinness of the shell.

Radiating striae crossing the exterior surface rather angular, subequal, from 10 to 12 in a width of 5 mm. near the anterior margin of the shell.

Owing to the thinness of the shell, it occurs usually in a fragmentary condition. The fragments rarely are preserved by collectors. The most satisfactory specimens consist of single valves adhering by one of their surfaces to the rock. The vertical range of *Strophomena hallie* needs further study. It probably extends throughout the Eden, but the species is common only at certain horizons in the middle or Southgate division of the Eden.

Strophomena hallie was described from 150 feet above the Ohio River, at Cincinnati, Ohio, from strata evidently belonging near the center of the middle or Southgate member of the Eden, but it is listed by Nickles also from the lower or Economy member. West of Foster, in the northwestern corner of Bracken county, and also opposite Utopia, several miles east of Wellsburg, in Kentucky, *Strophomena hollie* occurs along the railroad at the level of the lower Eden, but it may have slipped down the hill.

Along the railroad, southeast of Maysville, Kentucky, the following section is exposed:

Mount Hope member, with *Amplexopora septosa, Batostoma maysvillensis, Callopora communis, Callopora nodulosa, Constellaria prominens, Escharopora falciformis, Heterotrypa* sp., *Perenopora vera,* and *Strophomena maysvillensis.*
Limestone and clay ..... 5 ft. 6 in.
Chiefly clay, with *Dekayella ulrichi* and *Callopora sigillarioides,* belonging to upper or McMicken member of the Eden ..... 3 ft.
Limestone and clay ..... 14 ft. 6 in.
Chiefly clay, with *Dekayella ulrichi* ..... 5 ft. 6 in.
Chiefly clay, with some limestone, containing *Dekayella ulrichi, Callopora onealli,* and, near the middle, also several large specimens of *Platystrophia,* resembling *Pl. ponderosa* ..... 9 ft. 6 in.
Chiefly clay, with a limestone layer at the top and bottom ..... 10 ft.
Clay, with *Batostoma implicatum, Ceramoporella milfordensis, Dekayella ulrichi,* and *Perenopora vera* ..... 3 ft. 6 in.
Limestone layers, wave-marked at the top ..... 2 ft.
Limestone with *Platystrophia,* 1 inch wide, very rare ..... 4 in.
Clay ..... 3 ft. 6 in.
Chiefly hard limestone ..... 2 ft. 6 in.
Clay ..... 3 ft.
Wave-marked limestone, with *Strophomena hallie* ..... 4 in.
Chiefly clay ..... 4 ft.
Limestone and clay, with *Strophomena hallie* rather common in some of the lower layers. *Constellaria* occurs in one layer near the base. Also, *Batostoma implicatum, Dekayella ulrichi, Perenopora vera,* and *Stigmatella clavis* ..... 12 ft.

From the preceding notes it may be seen that *Strophomena hallie* occurs at Maysville between 63 and 80 feet below the top of the Eden. This horizon is regarded as belonging to the upper part of the middle or Southgate member, although it has not been found possible to draw a sharp line between the upper and middle member, diagnostic fossils not having been found.

Strophomena hallie occurs also in the upper part of the tunnel cut, along the railroad, 2 miles northeast of Carlisle, Kentucky. It is common in the Eden in the railroad cut immediately east of the home of George Million, about 4 miles northwest of Richmond, Kentucky. At the latter locality, it occurs only a short distance below the massive Paint Lick or Garrard member, and is associated with a large form of *Platystrophia,* $1\frac{1}{4}$ inches in width, resembling a young quadrate *Platystrophia ponderosa.* Also *Fusispira terebriformis, Amplexopora septosa, Constellaria prominens, Dekayella ulrichi, Escharopora falciformis, Hemiphragma* sp., *Heterotrypa* sp., and *Perenopora vera.* In a general way, this

assemblage of fossils suggests the upper member of the Eden, possibly only the lower part of this member, since a similar *Platystrophia* occurs 35 and 55 feet below the top of the Eden at Maysville. *Strophomena hallie* is found at various localities along the railroad, from the George Million locality westward to beyond the tunnel, 1 mile west of Million Station. At some of these localities it evidently occurs as low as the middle member of the Eden. One of the specimens was remarkably triangular in form (*plate* II, *Fig. 2*). An eighth of a mile west of the tunnel, near the home of Marion Newby, *Strophomena hallie* occurs at the very top of the fossiliferous part of the Eden, at the base of the massive Paint Lick or Garrard member. Near this locality, it occurs also near the base of the Eden section, but not necessarily in rocks equivalent to the lower Eden at Cincinnati, Ohio, since the latter appear to thin out before reaching central Kentucky.

Strophomena hallie occurs near the top of the fossiliferous part of the Eden, just beneath the Paint Lick massive rock, about 1 mile east of the Dix River, along the road from Lancaster to Danville; also 1½ miles west of Bestonia, in the southwestern part of Mercer county. This may be the horizon also of *Strophomena hallie*, in the northern corner of Lincoln county, north of the cross road marked Hubble on the U. S. Geological Survey map. Faulting immediately south of the exposure introduces an element of uncertainty.

Strophomena hallie occurs about half-way between the top and the bottom of the Eden, along the railroad from Hatton to Consolation, in the first cut east of the home of Tom Woods, in the eastern part of Shelby county Since the lower Eden thins out in this direction, the horizon undoubtedly is middle Eden.

Strophomena hallie occurs also in the Rogers Gap division of the Eden at Sadieville, in the northern half of Scott county, associated with *Cryptolithus tessellatus* (*Trinucleus concentricus*), *Eridorthis nicklesi*, *Hebertella* sp., and *Clitambonites rogersensis*. At the base of this division, at Rogers Gap, *Crepipora venusta* and *Heteropora foerstei* also occur. This fauna, which is the basal fauna of the Eden in central Kentucky, shows, as a whole, numerous features not seen in any part of the Eden at Cincinnati, Ohio. It appears, however, to be represented there at least in part, since *Eridorthis* occurs occasionally at the base of the Eden at Brent, also 1 mile west of Eight Mile Creek, and at Ivor, still

farther up the Ohio River. On the other hand, the typical lower Eden seems to disappear southward before reaching Scott county. As a matter of fact, similar faunal changes are noted in tracing the Fairmount fauna from Cincinnati southward. Possibly the simplest explanation would be that quite dissimilar faunas existed practically contemporaneously in different parts of the Cincinnatian areas at different times.

Directly north of Blanchet, in the southern part of Grant county, a species of *Strophomena* occurs, associated with *Amplexopora septosa, Callopora nodulosa, Coeloclema alternatum, Constellaria plana,* and *Heterotrypa* sp. Since *Heterotrypa* occurs also at the top of the fossiliferous part of the Eden beds, just beneath the Paint Lick or Garrard division, at the George Million locality, west of Richmond, the chief reason for regarding the exposures north of Blanchet as Mount Hope is the absence of *Dekayella ulrichi,* although it is regarded as very low in the Mount Hope, probably at its base.

Possibly *Strophomena hallie* is the ancestral form of *Strophomena maysvillensis.*

At Vevay, in Indiana, the upper Eden, containing *Amplexopora septosa,* and *Dekayella ulrichi-robusta,* is estimated at 58 feet in thickness. *Strophomena hallie* occurs 16 feet below the top of the middle Eden, and also at various horizons between 40 and 58 feet below the top of this division. *Aspidopora newberryi* occurs 60 feet below; *Monotrypa turbinata,* 65 feet below, and *Stigmatella nana,* 68 feet below the top of the middle or Southgate division of the Eden. These bryozoans are regarded as lower Eden, usually. This gives such a great thickness of lower Eden as far west as Vevay that it is difficult to believe that the lower Eden practically has disappeared at Sparta, in the southwestern corner of Gallatin county, Kentucky, unless the bryozoans mentioned have a greater vertical range than supposed hitherto.

Aspidopora newberryi, Callopora onealli, and *Crepipora venusta* occur on the river bank, a quarter of a mile west of Markland, about 3 miles east of Vevay, at the base of the Eden section. *Strophomena hallie* was collected also about 60 feet above the base of the Eden, 8 miles east of Vevay, opposite Warsaw.

At the junction of Mud Lick and South Fork, half a mile south of Milton, in Ohio county, Indiana, *Strophomena hallie* occurs about 85 feet below the top of the Eden, in the upper part of the middle

or Southgate division of the Eden, associated with *Batostoma jamesi, Callopora nodulosa, Coeloclema alternatum,* and *Dekayella ulrichi.*

Strophomena hallie is known at present only from the Eden of Kentucky, Ohio, and Indiana. If the Eden be correlated with the Frankfort shales of New York and the Sevier shale of the southern Appalachians, then the absence of any representatives of *Strophomena hallie* in these strata is significant. In the equivalent strata along the northern parts of Lake Huron and thence along the southern shore of Georgian Bay to the vicinity of Toronto, no species of *Strophomena* is known. The Eden is entirely absent in the northern part of the Mississippi Valley. From these data it seems probable that *Strophomena hallie* is a species of southern origin. This conclusion is favored also by the much greater abundance of *Strophomena hallie* in central Kentucky, and thence eastward as far as Maysville, than farther northward and northwestward, in Ohio, Indiana, and the northwestern exposures of Kentucky. A similar conclusion might be reached also from the presence of *Strophomena hallie* in the southern fauna at the base of the Eden section as exposed in central Kentucky. This southern fauna includes *Eridorthis nicklesi, Clitambonites rogersensis, Heteropora foerstei,* a species of *Hebertella,* and other species not known in the contemporaneous strata farther northward, or but rarely found there. These lower strata, forming the Rogers Gap division of the Eden, present an assemblage of species so different from the lower or Economy member of the Eden that there is a tendency to classify them with the middle Eden. They appear, however, to indicate rather how far northward the southern type of Eden had progressed locally during the deposition of the earlier part of the Eden.

Strophomena hallie belongs to the group of shells characterized by a weak delimitation of the muscular area of the pedicel valve, especially anteriorly. This area is not flabellate, nor is it extended anteriorly into a gap; its general form is roundish. The radiating striae, although not coarse, tend to be coarser than those of the *Strophomena planumbona* type of shells. *Strophomena hallie* is regarded as a precursor of *Strophomena maysvillensis,* a much more coarsely plicated species, ranging from the base of the Mount Hope to the upper parts of the Fairmount members of the Maysville.

Strophomena millionensis, sp. nov.

(Plate I, Figs. 9 A, B, C; Plate X, Fig. 14)

About 1 mile west of Million, in Madison county, Kentucky, the railroad passes through a tunnel. An eighth of a mile west of the tunnel, at the Marion Newby locality, the base of the Eden is exposed 10 feet above the railroad. A short distance west of this locality, the base of the Eden contains, in addition to numerous specimens of *Plectambonites sericea*, a few of *Dalmanella multisecta*, and an occasional specimen of the trilobite familiarly known as *Trinucleus concentricus*, also a small species of *Strophomena*. The largest specimen of this species, found so far, has a width of 19 mm. and a length of 13.5 mm. The relation of length to width, however, varies, being in most specimens about 14 to 17. The outline of the shell is subquadratic, the postero-lateral angles being rectangular, or between 80 and 90 degrees, with a tendency toward rounding at the tip of the angle in some specimens.

The brachial valve is flattened posteriorly, this flattening extending forward for about half the length of the shell, beyond which the sides of the shell slope toward the antero-lateral margins, producing a low, broad, median elevation anteriorly, whose crest makes a moderate angle with the flattened posterior part of the valve.

The hinge-area of the pedicel valve has a height of about 1 mm. at the beak; it forms an angle of about 125 to 130 degrees with the general plane of the shell. The sides of the delthyrium form an angle of 80 degrees, and the deltidium is evenly convex. The posterior half of the valve is gently convex, with a variable amount of flattening toward the postero-lateral margin. The anterior half is characterized by a broad and shallow median depression or sinus, corresponding to the median fold on the opposite valve. At the anterior margin of this fold and sinus the shell frequently is slightly produced, resulting in a slightly triangular, rather than evenly convex outline.

The radiating striae are rather coarse. Usually about 5 striae occupy a width of 2 mm., but on some parts of some shells the number may be as low as 4, or as high as 6 in the same width.

The general appearance of the shell closely resembles that of *Strophomena sulcata*. The chief difference appears to be that in *Strophomena millionensis* the spaces between the radiating striae

usually are wider, and, in most of the specimens, the relative width, compared with the length, is less.

Owing to the presence of these shells in the lower part of the Eden formation, the question arises whether the forms under discussion might be depauperate specimens of *Strophomena hallie*. It is then noted that, while the coarseness of the striae is about the same, there is an important difference shown by the pedicel valve. In *Strophomena hallie*, the pedicel valve is concave except in the immediate vicinity of the beak. In *Strophomena millionensis*, however, the shell is elevated from the umbo anterior to the beak as far as the antero-lateral margins, resulting in two divergent areas of elevation bordering the very broad and shallow median depression already described.

Some of the specimens of *Strophomena scofieldi*, from the base of the Trenton of Minnesota, present a low median fold on the brachial valve and a corresponding very shallow sinus on the pedicel valve; however, judging from a set of specimens kindly sent me by Prof. F. W. Sardeson, the majority of specimens do not show the sulcation, the latter not being in any strict sense characteristic of the species. The specimens attain a width of about 20 mm. The pedicel valves are flattish, except near the beak. The brachial valves are moderately convex, though slightly flattened at the beak. The number of radiating striae is about 8 in a width of 2 mm.

It is not certain that *Strophomena millionensis* is the precursor of *Strophomena sulcata*, or of any of the later species having this form of shell. Specimens having this form may not have constituted a distinct phylum within the genus *Strophomena*, but may have originated separately, at different times, from species of the ordinary form. Thus, *Strophomena sinuata* may have originated from *Strophomena maysvillensis*, and *Strophomena millionensis* may have originated from the same species which gave rise to *Strophomena hallie*. The sulcate forms of *Strophomena scofieldi* evidently originated from the ordinary, not sulcated forms of this species. From what species, however, could *Strophomena sulcata* have had its origin, if not from *Strophomena sinuata?*

Strophomena maysvillensis, Foerste[4]

(Plate II, Figs. 4 A, B, C, D, E, F, G, H, I, J)

Strophomena maysvillensis is closely related to *Strophomena planoconvexa.* On the average, however, it is a larger and longer species, and the outline frequently is subtriangular, owing to the downward deflection of the antero-lateral parts of the brachial valve. The sides of the shell frequently converge posteriorly, the hinge-line being shorter than the width of the shell across the middle. Sometimes the sides meet the hinge-line at right angles, and occasionally even at the slightly acute angle of about 80 degrees. The pedicel valve is only moderately concave toward the middle, or even is almost flat, but the brachial valve frequently is rather strongly convex, especially in the more triangular specimens. In the broader, less triangular forms, the convexity usually is not conspicuously greater than that of typical specimens of *Strophomena planoconvexa.* The flattening of the brachial valve anterior to the beak is nearly obsolete. The ratio of the length of the shell to the length of the hinge-line averages between 0.84 and 0.87, but may be as low as 0 70, or as high as 1.00; the ratio of the convexity of the shell to the length frequently equals 0.40, but shells of less convexity are common. Hinge-area high, forming an angle of about 45 degrees with the plane of the pedicel valve.

The deeply impressed muscular area of the pedicel valve is nearly circular in form, bordered on each side by a strongly elevated, sharp, curved ridge, deflected slightly forward at the gap at the anterior margin of the area. The interior of the pedicel valve is thickened a short distance within the anterior and lateral margins of the shell. The marginal part of the valve, exterior to the thickened part, frequently has a width of 2 mm. anteriorly, the distance across the thickened area being 4 or 5 mm. at the median parts of the shell. This thickened area or border is crossed by vascular grooves and ridges, and the median part is connected with the anterior gap of the muscular area by rather indistinct median grooves and ridges.

The posterior outlines of the adductor areas of the brachial valve are distinctly defined by the callosity beneath the cardinal

[4] *Denison Univ. Bull.,* vol. xiv, p. 212, 1909.

process, and the anterior extremities of the crural plates. The latter curve rather strongly forward. A low median ridge extends forward from the cardinal process, between the adductor areas. Anterior to a line connecting the anterior margins of the adductor areas, there frequently is a median depression, bounded laterally by the inner pair of vascular ridges which are parallel to the median parts of the shell. The narrow posterior extension of this inner pair frequently may be distinguished from the median ridge which extends forward from the cardinal process. The outer pair of vascular ridges is low, broad, and rather indistinct, terminating posteriorly at the anterior margin of the adductor areas.

The radiating striae on the exterior surface are rather coarse, agreeing in this respect with those of *Strophomena planoconvexa*. On the pedicel valve, 10 to 12 striae occur in a width of 5 mm. about 25 mm. from the beak. The same number of striae occur on many of the brachial valves, but here sometimes 14 and 15 striae are found in the same width. Frequently the striae appear coarser along the middle and posterior parts of the shell, becoming finer and less conspicuous along the anterior margin of the shell.

In the younger stages of growth, the postero-lateral angles of the shell are more nearly rectangular. In adult specimens these angles often are more or less rounded, and the posterior part of the lateral outlines converges slightly toward the hinge-line.

The type specimens of *Strophomena maysvillensis* were found in the lower part of the Fairmount bed, along the railroad, 2 miles southeast of Maysville, Kentucky.

At Maysville, in Mason county, Kentucky, the base of the Fairmount is placed at the base of the strata in which *Strophomena maysvillensis* is most abundant. This part of the section is $18\frac{1}{2}$ feet thick. It consists, near the base, of fairly massive limestone, weathering, toward the top, to shaly limestone interbedded with more solid layers. The overlying argillaceous rock section, about 50 feet thick, is nearly unfossiliferous, and is correlated with the Tate layer, typically exposed in Madison county. Beneath the Fairmount, *Strophomena maysvillensis* is found in small numbers down for a vertical distance of 22 feet, in strata regarded as corresponding to the Mount Hope member, typically exposed at Cincinnati.

A similar distribution of *Strophomena maysvillensis* in the Mount Hope and Fairmount members has been noted as far south as

Madison county, and thence westward. Along the southwestern line of Madison county, about 1 mile north of Paint Lick, the following section is exposed.

Base of Tate layer.
Argillaceous limestone with *Platystrophia ponderosa* ..... 4 ft.
Unfossiliferous argillaceous shale ..... 8 ft.
Shaly limestone with *Orthorhynchula linneyi* and *Platystrophia ponderosa* common ..... 24 ft.
Limestone and limestone rubble with *Platystrophia ponderosa* .. 15 ft. 6 in.
Strophomena maysvillensis at top, middle, and base of section, but not common ..... 9 ft.
Interval ..... 6 ft.
Strophomena planoconvexa rare.
Interval ..... 7 ft. 6 in.
Strophomena maysvillensis very abundant ..... 2 ft.
Base of Fairmount.
Argillaceous limestones interbedded with clay. *Strophomena maysvillensis* common on the upper surfaces of many of the limestone layers, but not as abundant as at the base of the Fairmount ..... 28 ft.
Brachiospongia laevis.
Argillaceous limestone with *Strophomena maysvillensis*, forming the base of the Mount Hope ..... 2 ft. 6 in.
Cross-bedded, argillaceous limestone, forming the top of the massive argillaceous rock section which may be called the Paint Lick division of the Garrard. About 6½ feet below the top of this section *Strophomena maysvillensis* makes its first appearance. The total thickness of the Paint Lick division is about ..... 60 ft.

In the preceding section, the occurrence of *Strophomena maysvillensis* in the upper part of the Paint Lick section should be especially noted.

Along the railroad, about 2 miles northwest of Richmond, the Tate layer has a thickness of about 30 feet. Most of it is thin-bedded or shaly. The following section is exposed.

Base of Tate layer.
Orthorhynchula linneyi very abundant ..... 5 ft. 6 in.
Orthorhynchula linneyi associated with *Platystrophia ponderosa* .. 5 ft. 6 in.
Rough argillaceous limestone with *Platystrophia ponderosa* .... 5 ft. 6 in.
Interval ..... 5 ft. 6 in.
Escharopora hilli and *Strophomena planoconvexa* ..... 5 ft. 6 in.
Strophomena maysvillensis in moderate numbers near top and resembling *Strophomena planoconvexa*. Typical forms of *Strophomena maysvillensis* near the base ..... 22 ft.
Mount Hope member, with *Strophomena maysvillensis* only in moderate numbers.

Orthorhynchula linneyi has not been traced northward beyond Madison county. From Madison county southward, as far as the middle of Lincoln county, it occupies a definite horizon, a short distance below the base of the Tate layer. Usually the highest level for *Strophomena maysvillensis* is below the *Orthorhynchula* horizon. However, at Givens Station, 3 miles east of Shelby City, and at the bridge 1 mile west of Lincoln county, *Orthorhynchula* occurs, associated with *Strophomena maysvillensis* at the highest levels occupied by the latter.

Along the railroad from Consolation to Benson, in the eastern part of Shelby county, the following section is exposed:

Depot at Consolation.
Interval ..... 18 ft.
Platystrophia ponderosa not common, rare below ..... 12 ft. 6 in.
Strophomena planoconvexa at top and bottom ..... 4 ft.
Interval ..... 4 ft.
Strophomena planoconvexa, Strophomena sinuata and *Plectorthis neglecta* ..... 4 ft.
Limestone with *Strophomena planoconvexa* ..... 7 ft.
Lowest *Platystrophia ponderosa.*
Clay ..... 2 ft.
Abundantly fossiliferous shelly limestone ..... 18 ft.
Strophomena planoconvexa at top and bottom ..... 2 ft.
Interval ..... 6 ft.
Strophomena maysvillensis common in rough limestone.
Dalmanella not common ..... 8 ft.
Strophomena maysvillensis not rare ..... 3 ft.
Base of Fairmount.
Limestone with *Dalmanella multisecta* and *Strophomena maysvillensis* at top. Lowest horizon for *Strophomena maysvillensis* occurs at base of this section ..... 29 ft.

The occurrence of *Strophomena maysvillensis* in the Mount Hope, as well as in the Fairmount, may be noted also along the pike from Shelbyville to Clay City. Northward, the number of specimens in the Mount Hope member diminishes rapidly. The following section is exposed near Port Royal, over 5 miles east of Turner Station, in the northeastern corner of Henry county.

Level of streets at Port Royal.
Interval with *Platystrophia ponderosa* at the base ..... 40 ft.
Platystrophia ponderosa abundant, *Monticulipora molesta* at the top ..... 10 ft.
Interval ..... 23 ft.

Sandy-appearing limestone.....5 ft.
Platystrophia ponderosa moderately abundant except toward base....23 ft.
Strophomena maysvillensis rather common.....1 ft.
Limestone with *Strophomena maysvillensis* not common.....19 ft.
Limestone with some thin sandy-appearing layers.....15 ft.
Rough limestone full of *Strophomena maysvillensis*.....9 ft.
Base of Fairmount.
Exposures poor, with *Strophomena maysvillensis*, *Platystrophia profundosulcata-hopensis*, a few specimens of *Dalmanella multisecta*, *Constellaria florida*, *Callopora nodulosa*.....11 ft.
Top of zone with *Dalmanella multisecta* abundant.

North of the Ohio River, in Indiana, *Strophomena planoconvexa* and its relative *Strophomena maysvillensis* occur in much smaller numbers and are restricted in their vertical range chiefly to two horizons, separated by a considerable interval in which no representatives of these species are known.

Similar features are presented at Williamstown, in Grant county, Kentucky. Here, along the railroad north of the town, *Strophomena planoconvexa* occurs at two horizons separated by an interval of 6 feet, and *Strophomena maysvillensis* is found about 30 or 35 feet lower, being abundant in a section about $7\frac{1}{2}$ feet thick. The *Strophomena planoconvexa* horizon unquestionably is of Fairmount age. It contains *Atactoporella* sp., *Callopora* sp., *Constellaria florida*, *Constellaria plana*, *Dekayia aspera*, *Heterotrypa* sp., *Homotrypa curvata*, and *Perenopora* sp.

At the *Strophomena maysvillensis* horizon, *Amplexopora septosa*, *Callopora nodulosa*, *Dekayella ulrichi*, and *Heterotrypa* sp. were collected. These suggest the base of the Mount Hope horizon, *Dekayella ulrichi* being regarded as limited to the Eden beds.

Strophomena occurs near the base of the Mount Hope and at the base of the Fairmount bed also in southern Indiana.

An eighth of a mile west of Brooksburg, in the southeastern part of Jefferson county, Indiana, *Strophomena* occurs $7\frac{1}{2}$ feet above the horizon at which *Dalmanella multisecta* is very common. At Vevay, in the southern part of Switzerland county, the top of the Eden contains *Dekayella ulrichi*, associated with very abundant specimens of *Dalmanella multisecta*. In the immediately overlying layers, *Platystrophia profundosulcata-hopensis* occurs. *Strophomena* ranges from 2 to 12 feet above the base of the Maysville. At several levels within the same range, *Plectorthis neglecta*

occurs. This part of the section forms the lower part of the Mount Hope bed.

Plectorthis neglecta is characteristic of the Mount Hope. It may be traced southward as far as Blanchet, in the southern part of Grant county, Kentucky, and eastward as far as Georgetown, in Brown county, Ohio. Wherever *Strophomena* occurs a short distance below the *Plectorthis neglecta* horizon, it may be regarded as belonging to the lower part of the Mount Hope, although, as a matter of fact, the Mount Hope is better defined by the occurrence at a lower level, of the presence of *Dekayella ulrichi*, which ranges to the very top of the Eden, and the introduction, immediately above the *Dekayella ulrichi* zone, at the very base of the Mount Hope, of a rich bryozoan fauna, which is very characteristic of this horizon in southern Indiana, and which will serve as a more ready guide than *Plectorthis neglecta*, which is not always present.

The interval between the base of the Mount Hope and the Bellevue member, in southern Indiana, varies from 85 to 105 feet, as far as may be determined from a number of sections made where the exposures were clear, but the gradients along which it was necessary to make the measurements were long. At this Bellevue horizon, in Indiana, *Platystrophia ponderosa* is very abundant, while specimens of this species are far from common in the immediately underlying Fairmount strata.

A second horizon for *Strophomena* occurs between 30 and 40 feet below the abundant *Platystrophia ponderosa* horizon, or between 50 and 60 feet above the lower *Strophomena* horizon, which is found at the base of the Mount Hope. Both the upper and lower horizon with *Strophomena* are exposed 2 miles south of Jacksonville, on the Plum Creek road, about $3\frac{1}{2}$ miles north of Vevay; in the northeastern corner of section 25; also $7\frac{1}{2}$ miles northeast of Vevay, or 4 miles east of Jacksonville, in the southwestern corner of section 14, near the home of J. W. Evett, in Switzerland county; and a quarter of a mile northwest of Guilford, northwest of the home of George Friedenberg, in Dearborn county. The upper *Strophomena* horizon is exposed also half a mile northwest of Dillsboro Station, 40 feet below the *Platystrophia ponderosa* horizon, in Dearborn county, where the railroad is crossed by a road leading northward to Chesterville; and along

the upper part of the road ascending the hill east of Scott Chapel, along the eastern branch of Lock Lick Creek, 2 miles east of the J. W. Evett locality, or 3 miles north of Florence, in Switzerland county. At the latter locality the upper *Strophomena* horizon is underlaid by thin-bedded, argillaceous, sandy, brown shale, and this thin-bedded shaly material occurs at many localities in the same county at the same horizon, apparently the upper half of the Mount Hope bed.

At the lower horizon, in Indiana, the specimens of *Strophomena* are small, they have a more convex brachial valve and are regarded as more closely allied to *Strophomena maysvillensis*. At the upper horizon, the specimens of *Strophomena* are larger and flatter, and are regarded as *Strophomena planoconvexa*.

At most places, in Ohio, *Strophomena* occurs chiefly at the base of the Fairmount member, and, in fact, *Strophomena planoconvexa* was used by Mr. John M. Nickles to mark the plane between the Mount Hope and the Fairmount. Occasionally, however, *Strophomena* occurs also here at two horizons. For instance, at Allandale, 10 miles northeast of the center of Cincinnati, *Strophomena planoconvexa* occurs at the base of the Fairmount, while at a road crossing the railroad half a mile eastward, *Strophomena maysvillensis* occurs at a lower level in the Mount Hope.

Strophomena maysvillensis occurs in considerable numbers also along the Cumberland River, from the northwestern corner of Wayne county to the northeastern part of Cumberland county. Here it is associated with *Orthorhynchula linneyi*, *Escharopora hilli*, and *Cyrtoceras vallandinghami*, all indicating the top of the Fairmount as exposed in central Kentucky. *Strophomena maysvillensis*, associated with *Orthorhynchula linneyi*, is found also in Tennessee, occurring as far south as the area covered by the Columbia folio.

Strophomena maysvillensis is known at present from Tennessee, Kentucky, Ohio, and Indiana. In Kentucky, it is most abundant and of largest size in the central part of the state and thence northeastward as far as Maysville. Moreover, in this part of the state it begins its range as low as the base of the Mount Hope, while northward and northwestward it is rare or absent until the top of the Mount Hope is reached. These facts suggest the derivation of *Strophomena maysvillensis* from some southern source. It may be

said to characterize the Maury phase of the Fairmount, as exposed typically in Maury county, Tennessee, in southern Kentucky, along the Cumberland River, and in central and east-central Kentucky.

It is difficult at times to determine whether the purposes of science will be served best by emphasizing the close relationship of different forms and by grouping them all under the same specific name, or by emphasizing their differences to the extent of assigning them even to different species. The present is such a case. *Strophomena maysvillensis* is closely related to *Strophomena planoconvexa*. Though occurring at different horizons, locally, they occasionally are associated, and apparently are connected by intermediate forms It is unfortunate that Hall's types of *Strophomena planoconvexa* were chosen from the smaller, flatter, and more quadrate forms, especially if *Strophomena maysvillensis*, of much more extended vertical and horizontal range, is to be regarded as merely the more vigorous form of *Strophomena planoconvexa*.

Strophomena planoconvexa, Hall[5]

(*Plate I, Figs. 1 A, B, C, D, E, F; 2 A, B*)

The type specimens of *Strophomena planoconvexa,* preserved in the American Museum of Natural History, in New York City, and numbered 919-2, are labelled as coming from Cincinnati, Ohio. They are small individuals, the larger one about 25 mm. in width, and belong to a form not rare at a very limited vertical range at the base of the Fairmount bed. At the same horizon, in Kentucky, half a mile north of Crescent Springs Station, on the Queen and Crescent Railroad, south of Cincinnati, an individual was found, 39 mm. wide, 28 mm. long, and 8.5 mm. in convexity.

This species is remarkable for the slight concavity of the pedicel valve. It is evident that the valve in its earlier stages of growth was slightly convex, especially near the beak, and had attained a length of 11 to 14 mm. before reversing its curvature. This concavity frequently does not exceed 1 mm in specimens 35 mm. wide.

The brachial valve usually is only moderately convex. This convexity frequently does not exceed 6 mm. in specimens 33 mm.

[5] *New York Paleontology,* vol. i, p. 114, 1847.

wide, but may equal 9 mm. in the same width. The ratio of the length of the shell to the width usually varies between 0.70 and 0.80.

The muscular area of the pedicel valve is shallow, but the curved lateral border is distinct, especially along the exterior edge. Anteriorly, this lateral border is deflected slightly forward, producing a median gap. The median ridge traversing the muscular area is low and rather narrow anteriorly. There are only faint traces of median vascular markings or of any thickening of the shell toward the anterior margin. The interior surface, in general, is smooth.

In addition to the cardinal process, the crural plates, and the low median elevation, the interior of the brachial valve may show the posterior part of the inner pair of the vascular ridges frequently found in species of *Strophomena*.

The radiating striae are much coarser than in most species of *Strophomena*. This coarseness is especially noticeable over the middle regions of the shell, and even toward the beak, where the radiating striae usually are comparatively fine. About 7 to 9 striae occupy a width of 5 mm. near the margin of the brachial valve, while 7 to 10 occur in the same width on the pedicel valve.

The type specimens of *Strophomena planoconvexa* were found at Cincinnati, Ohio, and here they occur at the base of the Fairmount bed. They are found at this horizon as far north as the clay banks on the West Fork of Mill Creek, southwest of Glendale; 1 mile east of Reading; and at Allandale, $3\frac{1}{2}$ miles northeast of Madisonville, in Hamilton county. Also, northeast of Crescent Springs, along the railroad, in Kenton county, Kentucky; and nearly 2 miles west of Verona, in the southern part of Boone county. The upper horizon of *Strophomena* along the railroad north of Williamstown, in Grant county, Kentucky, consists of *Strophomena planoconvexa* at the base of the Fairmount, and this horizon, with the same form of *Strophomena*, may be traced as far south as Mason. The upper horizon for *Strophomena*, from Guilford, in Dearborn county, to the vicinity of Vevay, in Switzerland county, in Indiana, is approximately at the same horizon, the base of the Fairmount, and contains the same species, *Strophomena planoconvexa*.

Along the railroad from Consolation to Benson, in the eastern part of Shelby county, Kentucky, the specimens of *Strophomena* in the Mount Hope and in the lower part of the Fairmount section,

11 feet thick, are identified as *Strophomena maysvillensis*, while the specimens in the overlying part of the Fairmount, 47 feet thick according to measurements taken along a long gradient, are more like the typical specimens of *Strophomena planoconvexa*

Somewhat similar phenomena are noted in Madison county, Kentucky. Here the specimens of *Strophomena* which occur in the upper part of the Fairmount, beneath the Tate layer, more closely resemble *Strophomena planoconvexa*, while those in the lower half of the Fairmount, and in the Mount Hope bed, are identified as *Strophomena maysvillensis*. These features are well presented by the section along the railroad, several miles west of Richmond, and also by the road leading west from the Richmond pike, 1 mile north of Paint Lick.

Strophomena occurs in quite considerable numbers, associated with *Orthorhynchula linneyi*, along the Cumberland River, from the northwestern edge of Wayne to the northeastern part of Cumberland county. Some of the specimens have the flat, more quadrate form characteristic of the type specimens of *Strophomena planoconvexa*. Others have the more triangular form, characteristic of *Strophomena maysvillensis*.

At the time when the specific name *Strophomena maysvillensis* was proposed, it seemed possible to distinguish two species, one of which was smaller, flatter, and more quadrate in outline, while the other was a larger and more triangular form, more strongly arched across the middle. The fact that in some parts of the field, the flatter, more quadrate form occurred at a higher horizon, rather favored this view, even if this separation by horizons could not be maintained when tracing these fossils to other areas. However, more recently, the conviction has grown that the larger, more triangular form is likely to be present wherever conditions strongly favored the development of the species, so that the specimens grew larger, developed more vigorous shells, and became very numerous. On the contrary, where conditions were less favorable, the specimens were smaller, the valves were thinner, and flatter, and the outline approached more nearly the ordinary quadrate form.

From this point of view, *Strophomena maysvillensis* may be regarded as simply a more healthy form of *Strophomena planoconvexa*, the type specimens of the latter having been collected so far north of the area in which the growth of the species was most vigorous, that only the more depauperate specimens were found.

In a similar manner, the flatter, more quadrate forms occur in central Kentucky, chiefly in the upper part of the Fairmount, especially where the number of specimens is small, and the species evidently is disappearing.

Regarding *Strophomena maysvillensis* as only the more vigorous form of *Strophomena planoconvexa*, the distribution of the former should be added to that of the latter, in order to secure a complete account of the geographical and vertical distribution of *Strophomena planoconvexa*.

Strophomena sinuata, Meek[6]

(Plate I, Figs. 3 A, B, C)

Strophomena sinuata was described by Meek, probably from material supplied by U. P James. In the James collection, in the Walker Museum at Chicago University, there are several entire specimens, numbered 56, and labelled as types of *Strophomena sinuata*, among which none of the specimens figured by Meek (*Ohio Paleontology*, vol. i, plate 5, Figs. 5, *a–d*) could be identified. They probably are a part of the series from which Meek secured his material. Similar statements may be made of most of the other Cincinnatian specimens figured by Meek, unless the specimens were very rare and were returned to some private collection.

Compared with *Strophomena sulcata*, the shells of *Strophomena sinuata* are somewhat larger, frequently equalling 25 mm. and sometimes attaining 30 mm. in width. The general outline is about the same, and usually there is no great difference in the amount of sinuosity of the valves anteriorly, although comparatively deep and narrow sinuses are not uncommon in *Strophomena sulcata*, and are comparatively rare in *Strophomena sinuata*. The chief difference consists in the coarseness of the radiating striae. Of these there are about 6 to 7 within a width of 5 mm. near the anterior margin, or 36 to 40 within 1 cm. of the beak, occasionally equalling 42 or even 45. Usually the brachial valve appears more convex from front to rear; this is due partly to the fact that the median elevation curves downward below the general plane of the flattened area which is located anterior to

[6] *Ohio Paleontology*, vol. i, p. 87, 1873.

the beak; partly it is due also to the greater convexity of the sides of the valve, anterior to the postero-lateral angles. The umbonal part of the pedicel valve, anterior to the beak, appears less elevated, and the general appearance of the posterior half of the valve is somewhat flatter.

The interior of the valves is very similar to that of *Strophomena sulcata*. It is strongly striated radially, owing to the thinness of the shell. The muscular area of the pedicel valve is circular, it is well outlined laterally but not anteriorly. The two-lobed cardinal process, the divergent crural plates, and the median ridge, extending forward from the callosity immediately anterior to the cardinal process, are well developed on the interior of the brachial valve. The diductor area is poorly defined.

Strophomena sinuata was described from the upper part of the Fairmount, at Cincinnati, Ohio, at a horizon which is a considerable distance above the *Strophomena planoconvexa* level, at the base of the Fairmount. It occurs also at Madisonville, Ohio. At Bald Hill, 1 mile west of Georgetown, in Brown county, Ohio, *Strophomena sinuata* is not rare at a horizon 45 feet above that part of the section, $6\frac{1}{2}$ feet thick, in which *Strophomena maysvillensis* is common. A few specimens of *Strophomena planoconvexa* occur both above and below this *Strophomena sinuata* horizon for a distance of 10 feet. At Bald Hill, the specimens of *Strophomena sinuata* have an appearance as though they might have been derived from some nasute form of *Strophomena maysvillensis;* in other words, as though they might be depauperate specimens of the latter. *Strophomena sinuata* occurs also as an occasional loose specimen west of Mount Sterling, 3 miles north of Vevay, in Switzerland county, in Indiana. A single specimen, resembling *Strophomena sinuata,* was found 50 feet above the base of the section in which *Strophomena maysvillensis* is very common, and which here is regarded as at the base of the Fairmount.

Strophomena sinuata, although resembling *Strophomena millionensis,* certainly was not derived from that species. It has been found so far only near the upper limits of the range of *Strophomena maysvillensis.* In Ohio and Indiana it is known only near the northern limits of the geographical range of that species. It is also listed by Ulrich from the *Strophomena maysvillensis* horizon in the Maury phase of the Fairmount, within the limits of the Columbia folio, in Tennessee. I have never seen any very typical

specimens in Kentucky. The species, owing to its associations, is regarded as of southern origin. This is to be expected, if it is a derivation from *Strophomena maysvillensis.*

Strophomena concordensis, Foerste[7]

(*Plate III, Figs. 1 A, B, C, D, E, F, G, H, I, J, K, L, M, N*)

Strophomena concordensis evidently is closely related to *Strophomena nutans,* but it is a much larger species than the typical form of the latter. Specimens frequently attain a width of 42 mm., a length of 30 mm., and a convexity varying from 11 to 15 mm. The convexity of the more strongly arched specimens varies between 0.44 and 0.48, although frequently less. In *Strophomena wisconsinensis* this ratio may equal 0.55, or even 0.60. The lateral outlines, posterior to the middle of the shell, frequently are subparallel or only moderately divergent, as in *Strophomena nutans,* but more frequently the outline of the shell is subtriangular, the postero-lateral angles varying from 75 to 55 degrees. In *Strophomena nutans,* the outlines more commonly are subpentagonal, and shells having a subtriangular outline are far less common. The subtriangular appearance of the brachial valve is strengthened by the downward deflection of the antero-lateral parts of the valve. The posterior part, within 10 mm. of the hinge-line, usually is distinctly flattened, but the concavity of the valve immediately anterior to the beak is almost imperceptible. The convexity of the umbonal parts of the pedicel valve, immediately anterior to the beak, is moderate, but is much more readily perceptible than the corresponding almost imperceptible umbonal concavity of the brachial valve. The concavity of the middle part of the pedicel valve varies, of course, with the general convexity of the brachial valve. In extreme cases it is deeply concave, the maximum concavity being at or immediately anterior to the middle of the shell. Oblique wrinkling of the shell along the hinge-line may be detected occasionally.

The radiating striae of the brachial valve are very fine near the beak, but become coarser toward the anterior margin of the shell. Frequently every third, fourth, or sixth striation is more prominent, especially anteriorly, but in some specimens they alternate in

[7] *Denison Univ. Bull.,* vol. xiv, p. 213, 1909.

size or are approximately equal toward the anterior margin; or they may be very nearly equal in size even posteriorly. About 25 mm. from the beak they usually vary between 12 and 16 in a width of 5 mm., but occasionally this number is increased to 18, 20, and even 24. The radiating striations of the pedicel valve are about equal to those of the brachial valve posteriorly, but anteriorly they are more numerous, frequently equalling from 20 to 24 in a width of 5 mm., although occasionally as low as 17, and even 14. When every fourth striation is conspicuously stronger than the intervening ones, their number usually equals about 6 in a width of 5 mm.

Aside from the larger size of the shell, the interior of the pedicel valve presents the most characteristic diagnostic features of this species. The thickened border along the anterior and lateral margins of the valve is never as prominent and abrupt, nor as well defined along the inner edge as in the case of *Strophomena nutans*. The absence of the strong vertical thickening along the median anterior nasute edge of the pedicel valve, and of the strong vascular markings on the upper and inner side of this thickening, is especially characteristic. Usually, the thickening along the anterior and lateral margins of the pedicel valve, in *Strophomena concordensis*, is only moderate; the inner margin of this thickened border is rather vaguely defined, and the border is crossed by vascular markings extending as far as the anterior edge of the shell. These vascular markings extend fully a centimeter from the anterior edge. The muscular area is deeply impressed and is limited by a sharp, prominent border, deflected anteriorly so as to produce a median gap. The muscular area is crossed by a median ridge, on each side of which are the impressions left by the adductor muscles.

In the *Ohio Naturalist*, vol. XII, pl. XXII, 1912, Fig. 10 A illustrates a typical interior of the brachial valve, Fig. 10 B presents an aberrant form of the pedicel valve in which the marginal thickening lies nearer the edge, is more distinctly defined posteriorly, and is more abrupt anteriorly than usual.

The interior of the brachial valve does not present any distinguishing features. The two-lobed cardinal process, the strongly divergent crural ridges, the median ridge dividing the muscular area anterior to the cardinal process, and the four vascular ridges and intermediate sinuses along the median parts of the valve are

distinctly shown. Of these ridges, the two lateral ones terminate posteriorly within the impressions of the adductor muscles. Posteriorly, the interiors of both valves occasionally are pitted. Aside from the markings already mentioned, numerous minute papillae often may be seen under a lens, the surface appearing smooth to the unaided eye.

From *Strophomena wisconsinensis* this species may be distinguished by its more triangular, subnasute outline, and the finer striation of the exterior surface. The height of the hinge-area also is much less.

The type specimens of *Strophomena concordensis* were found in a partially indurated blue clay layer at the top of the Arnheim bed, a short distance south of the railroad bridge, east of Concord, Kentucky, at creek level.

Strophomena concordensis ranges from the southwestern corner of Butler county, in Ohio, southeastward to Maysville and Concord, along the northern edge of Kentucky. In all of this distance its horizon is confined to the top of the Arnheim, usually in a chunky, bluish, argillaceous rock, although in the southern part of Adams county this gives way to more or less limestone, and southeast of Maysville, in Kentucky, the *Strophomena concordensis* horizon consists practically entirely of limestone layers. Eastward, the chunky, argillaceous rock varies from 5 to 7 feet in thickness, but north of Lebanon, Ohio, its thickness is 4½ feet; opposite the Chautauqua grounds at the southern edge of Montgomery county, it is 3 feet; and westward it is still thinner, disappearing before reaching the western boundary of Butler county. At Oregonia, *Strophomena concordensis* is very rare and occurs only at the base of the chunky argillaceous rock. This locality, and the one south of Lebanon, appear to mark the northern boundary of the area of distribution for this fossil. At many of the localities farther southward, *Strophomena concordensis* occurs in great abundance throughout the entire thickness of the chunky argillaceous rock, at the top of the Arnheim. The interval between this rock and the underlying *Dinorthis carleyi* horizon usually varies from 16 to 20 feet.

Among the areas at which *Strophomena concordensis* does not occur, notwithstanding the presence of the chunky, blue, argillaceous rock at the top of the Arnheim, is the mouth of Lick Run, opposite the mouth of Caesar Creek, in the northern part of War-

ren county; the exposures along Reservoir Creek, north of Lebanon; opposite the Chautauqua grounds, east of the Miami River, at the southern edge of Montgomery county; and 2 miles south of Jacksonburg, in the northern part of Butler county.

At Maysville, Kentucky, *Strophomena concordensis* occurs, associated with *Dalmanella jugosa* in a bluish limestone about 2 feet thick. Lithologically, the rock resembles the base of the Waynesville member, rather than the chunky argillaceous rock seen farther northward.

The most interesting section, however, is that at Concord, in the northern part of Lewis county, where *Strophomena concordensis* is limited to a vertical range of 1 foot, *Streptelasma canadensis* and *Columnaria alveolata* occuring 5 feet above this level, and *Streptelasma canadensis* being found also $5\frac{1}{2}$ feet below the *Strophomena concordensis* horizon. Nothing like this has been observed elsewhere and the section requires further study.

About 2 miles north of Hazelwood, Ohio, northwest of the corner at which Butler, Warren, and Hamilton counties meet, and also 1 mile south of Pisgah, in the same corner of Butler county, specimens of *Strophomena* occur, at the *Strophomena concordensis* horizon, which are comparatively flat and so little nasute anteriorly that they suggest *Strophomena planumbona* and the flatter forms of *Strophomena elongata* rather than *Strophomena concordensis*. In some of these specimens the anterior margin is evenly rounded. It should be noted, however, that they are not of full size, and that at a more advanced age they might have developed to a form more nearly resembling typical *Strophomena concordensis*. The largest specimens of the more quadratic type have a width of 26 mm. with a length of 19 mm., while the largest specimens of the *elongata* type have a width of 30 mm. with a length of 20 mm.

Strophomena concordensis represents a reintroduction of the *Strophomena vicina* type of shell. Its geographical range is limited to the area between Lewis county, in Kentucky, and the eastern part of Butler county, in Ohio. Here it occurs only at the very top of the Arnheim, in strata which perhaps had better be placed at the very base of the Waynesville member of the Richmond. It is not known from the Arnheim of the remainder of Kentucky, or from Indiana or Tennessee. It recurs in the Blanchester division of the Waynesville member in an almost

identical form, associated with *Strophomena nutans*. In fact, *Strophomena nutans* may be regarded as only a depauperate, gerontic form of *Strophomena concordensis*. The range of *Strophomena nutans* also is limited to the more northern exposures along the areas traversed by the Cincinnati geanticline, but, compared with *Strophomena concordensis*, its range is more extended, reaching from Lewis county, in Kentucky, to Dearborn county, in Indiana. Northward, *Strophomena concordensis* finds a near relative in *Strophomena concordensis-huronensis* along the northern parts of Lake Huron and along the southern shores of Georgian Bay. *Strophomena wisconsinensis*, from Wisconsin and Illinois, probably belongs to the same group.

The introduction of *Strophomena concordensis* at the close of the Arnheim was brief, and the accompanying species give no clue as to the direction from which this fauna might have come. In the Blanchester division, however, the related species is associated with *Strophomena neglecta*, which finds its nearest relative in *Strophomena planodorsata* from the Mississippi Valley, ranging from southern Tennessee northward to Minnesota and thence westward. Moreover, the Blanchester division contains also *Austinella scofieldi* and is included between two layers containing *Hebertella insculpta*, two species having an equally extended geographical range along the Mississippi Valley.

From these data it may be concluded that all of these species had some common origin. During the deposition of the Blanchester division of the Waynesville there apparently was a basin extending from Bath, Fleming, and Lewis counties, in Kentucky, northward and northwestward across Ohio, Indiana, and northern Illinois, so as to connect with the Mississippi basin. Apparently *Strophomena concordensis* represents merely one of the first incursions of the fauna which later had a much greater distribution. As far as its appearance in southwestern Ohio is concerned, it appears to have entered from some northern or northwestern source.

Strophomena concordensis-huronensis, var. nov.

(*Plate II, Figs. 1 A, B, C, D, E, F, G, H, J, K*)

In the Richmond group on Manitoulin Island, a species of *Strophomena* is very common at various levels between the *Heb-*

ertella insculpta horizon and a coral horizon, at least 40 feet farther up. At the *Hebertella insculpta* horizon, *Catazyga headi* occurs locally. *Strophomena sulcata* ranges from immediately above the *Hebertella insculpta* horizon upward for a distance of about 20 feet. *Protarea richmondensis, Columnaria alveolata, Calapoecia huronensis, Streptelasma canadensis,* and *Rhynchotrema perlamellosa* begin their range at the *Hebertella insculpta* horizon and continue their range at various intervals to the coral horizon already mentioned. Some of these species are found for a considerable distance beyond this coral horizon. The abundant species of *Strophomena,* here under discussion, ranges from the *Hebertella insculpta* horizon almost up to the coral bed. *Cyclonema bilix* and a small form of *Plectambonites sericea* occur in the lower half of this interval, and *Platystrophia clarksvillensis* also occurs at various levels. *Rhombotrypa quadrata* ranges from the *Hebertella insculpta* horizon upward for about 6 feet. *Zygospira kentuckiensis* ranges from about 17 feet below the coral horizon to layers overlying the coral bed. The latter is characterized by the great numbers of *Columnaria alveolata* and *Calapoecia huronensis* present. Specimens of *Tetradium* and of *Stromatocerium* occur. The chief feature of this coral horizon is not the presence of any characteristic species, not found above or below, but the abundance of *Columnaria* and *Calapoecia,* species which at other levels, especially at lower levels, occur only as isolated specimens.

In general, this section between the *Hebertella insculpta* horizon and the coral bed, 40, 50 or 60 feet higher up, is very suggestive of the upper or Blanchester division of the Waynesville member of the Richmond, while the overlying beds, containing *Beatricea undulata,* may be compared with the Saluda of Indiana and Kentucky. The most conspicuous feature of the lower division of the Richmond, on Manitoulin, is the absence of *Leptaena richmondensis,* a fossil extremely abundant in the Blanchester division of the Waynesville member. On the other hand, the presence of isolated specimens resembling *Strophomena neglecta* and *Strophomena nutans* is highly suggestive. The most striking feature of the section overlying the coral horizon is the absence of *Dinorthis subquadrata* and of *Strophomena vetusta.* It should be remembered, however, that the latter species were driven out of the Indiana and Kentucky Richmond,

by the Saluda invasion, probably from the north, and occur only in the basal layers of the Saluda.

With these preliminary remarks in mind, it will be possible to appreciate the significance of the specimens of *Strophomena* which are so abundant in the lower beds of the Richmond on Manitoulin.

Perhaps the most striking feature of these Manitoulin specimens is their general resemblance to *Strophomena concordensis* and to the similar specimens associated with typical *Strophomena nutans* at Clarksville, Ohio, and elsewhere in Cincinnatian areas. The latter are described under *Strophomena nutans*, and are regarded not merely as descendants of *Strophomena concordensis*, but also as the less aberrant forms of which typical specimens of *Strophomena nutans* are the retarded, gerontic individuals.

The general outline of the shell tends to be subnasute and subpentagonal. It is possible to cull out specimens in which this tendency is strongly marked, and to select others in which the convexity of the shell is more regular, and the general outline is about as evenly rounded as in *Strophomena planumbona*. However, shells in which the tendency toward a subnasute outline is only faint, are more common. The postero-lateral angles usually vary between 80 and 85 degrees, but they frequently are rectangular, and occasionally they may be as acute as 70 degrees. Not infrequently the shell is extended slightly at the hinge-line.

The brachial valve is flattened posteriorly for a distance of about 10 mm., after which the downward flexure of the shell begins. The maximum convexity usually occurs 12 to 15 mm. anterior to the beak. In the subpentagonal shells, the slope from here to the antero-lateral margins is somewhat more rapid than along the median line, thus giving the central part of the valve a slightly humped appearance. Usually the downward curvature of the shell is rather regular anteriorly, but occasionally it is quite abrupt. Sometimes the nasute character of the shell is very pronounced and occasionally an individual is found in which this nasute character is as prominent as in the figure of *Strophomena hecuba* published by Billings in *Paleozoic Fossils*, vol. I, p. 126.

The pedicel valve is rather strongly concave, especially in the more nasute specimens, frequently equalling 3 and 4 mm. in shells 22 to 30 mm. in length. Immediately anterior to the beak, the valve is distinctly convex, the reversal of curvature taking place between 12 and 15 mm. from the beak.

So many of the shells are obliquely wrinkled along the hinge-line that this feature may be said to be characteristic of the Manitoulin species, notwithstanding the numerous individuals in which this wrinkling is inconspicuous or absent. The angle made between the wrinkles and the hinge-line usually varies between 30 and 40 degrees. Radiating striae subequal or alternately larger and smaller, about 12 or 13 in a width of 5 mm., but ranging occasionally from as low as 10 to as high as 14 or 15. Individual specimens are found in which the alternation of single, stronger striae with three finer ones occurs, but the stronger striae rarely are prominent, and this type of striation is not characteristic of the species.

Interior of the pedicel valve very much as in *Strophomena concordensis*. The thickening along the border of the shell in the majority of specimens is low, and is crossed by shallow vascular grooves, which extend halfway from the anterior margin toward the muscular area, in some individuals almost reaching the latter. In other specimens, this thickening is greater and is more distinctly limited posteriorly, but its height rarely exceeds 2 mm., although in one specimen it equalled 3 mm. Only a single specimen (Fig. 8, plate XI) was found in which this thickening was as prominent and "knotted" along the median line as in the typical forms of *Strophomena nutans*. This smaller, gerontic individual may owe its form to the same conditions as those which gave rise to the numerous specimens which are included under typical *Strophomena nutans*, in Ohio and Indiana.

Interior of the brachial valve also essentially as in *Strophomena concordensis*. Crural plates making an angle of 50 degrees with the hinge-line. Posterior part of the adductor muscle scars sharply limited by the callosity which is anterior to the crural ridges and which unites with the median ridge separating the adductor areas. In most specimens, the subparallel ridges traversing the median parts of the valve anterior to the adductor areas, and limiting the vascular grooves, are not distinctly defined except within a short distance of these areas.

The chief difference between the Manitoulin specimens and *Strophomena concordensis* consists in the presence of the oblique wrinkles along the hinge-line. In *Strophomena concordensis*, from Ohio and adjacent Kentucky, the outline of the shell more frequently becomes subtriangular; when the shell is viewed from the side, the posterior flattened part of the brachial valve usually rises more abruptly above the plane passing through the margins of the valve; in consequence, the hump at which the downward flexure of this valve is greatest lies nearer the posterior part of the valve; the curvature from this hump toward the anterior margin usually is less, producing a long slope in this direction, with longer and somewhat flatter antero-lateral slopes, resulting frequently in the more triangular outline already mentioned. It should be emphasized, however, that the differences here noted are not characteristic of all the shells, and are not likely to be observed unless large collections of shells are at hand, in which case the general facies is that here described.

The chief interest in these Manitoulin specimens lies in the fact that from the central type here described, including the vast majority of specimens, there is a line of variation towards specimens which can not be distinguished from *Strophomena planumbona*, but which exist in much smaller numbers. A few specimens also show a line of variation toward *Strophomena nutans*. Individual specimens that can not be distinguished from typical *Strophomena planumbona*, *Strophomena planumbona-gerontica*, and *Strophomena nutans* also occur. Why should these specimens always be isolated?

It is not worth while comparing this species with *Strophomena hecuba* until the genus of that species is known. Its vertical range suggests *Strophonella* instead of *Strophomena*, and the interior of this species has not been described so far. Provisionally, the absence of indistinct concentric wrinkles will be sufficient to distinguish all of the variations of the *Strophomena concordensis* type.

The type specimens of the variety *huronensis* occur in great abundance at the eastern end of Manitoulin Island, at the Clay Cliffs, 3 miles north of Wekwemikongsing. This is the locality long known as Cape Smith, although this Cape lies several miles toward the northward. The clay cliffs are best reached by the long walk over large boulders along the shore. Specimens of the

variety *huronensis* are abundant in the glacial drift northwest of Wekwemikongsing. They are found in place 3 miles south of Little Current, and at numerous localities around Kagawong and Gore Bay. On account of their abundance elsewhere, their absence at Manitouaning, and south of the Indian village, 5 miles southwest of Little Current, should be noted. The same form occurs in the eastward extension of the Richmond, also a short distance above the *Hebertella insculpta* horizon, at various localities south of Cape Rich, and south of Cape Boucher, 2 miles east of Meaford, on the southern shore of Georgian Bay. The same fauna should occur also southeastward, at Streetsville, on the Credit River, and west of Manitoulin, at the northeast end of Drummond Island.

Near Meaford, Ontario, only the lower part of the Richmond section, for 14 feet over the *Hebertella insculpta* horizon, is richly fossiliferous. The overlying part of the Richmond section is formed by a thick series of reddish clays, and shales the latter more or less sandy.

Strophomena nutans, Meek[8]

(Plate III, Figs. 2 A, C, D, E; Plate IX, Fig. 15; Plate X, Figs. 2 A, B, C; Fig. 2 B on Plate III and Fig. 8 on Plate XI present similar features; Plate X, Figs. 3 A, B, C, D, and Plate IX, Fig. 16, approach Strophomena concordensis.)

The typical form of *Strophomena nutans* is from the upper or Blanchester division of the Waynesville bed, in Butler, Warren, and Clinton counties, Ohio. This species was described by Meek from material belonging to the U. P. James collection. In this collection, preserved in the Walker Museum, at Chicago University, there is a series of specimens, numbered 65, labelled as types of *Strophomena nutans*, and as coming from Richmond, Indiana. Among this series, only the specimen used for Fig. 1 *c*, on plate VI, of the *Ohio Paleontology*, could be found. The labelling, Richmond, Indiana, probably is entirely incorrect. However, even if the specimen was obtained from the vicinity of Richmond, it should be remembered that the nearest outcrop containing *Strophomena nutans* is 8 miles southwest of Richmond, 1½ miles south of Abingdon, on the eastern side of the Whitewater River.

[8] *Ohio Paleontology*, vol. i, p. 77, 1873.

The specimens represented by figures *A*, *B*, *C*, accompanying the original description, were 23 mm. wide and 21 mm. long. They have a sub-pentagonal outline. Anterior to a line drawn transversely across the center of the shell, the outline is broadly V-shaped, rounded at the anterior extremity. Posterior to this transverse line, the sides of the valve are only moderately divergent or nearly parallel. The posterior part of the brachial valve is flattened. From this flattened area, the shell is deflected strongly toward the anterior margin, especially toward the antero-lateral sides, producing a strongly convex, subnasute appearance, which suggested the term *nutans*. The pedicel valve is rather strongly concave, the maximum depression being about two-thirds of the length of the shell from the beak. The radiating striae are fine, every fourth one tending to be slightly more prominent. The muscular area of the pedicel valve is deeply impressed, and the border of this area rises sharply and prominently above the general surface. The interior of the valve is conspicuously thickened along the border, the amount of this thickening being greatest near the middle of the anterior border, where it presents a very steep slope, having a height of almost 8 mm. above the general plane of the margin of the valve. This thickened border is crossed by strongly impressed grooves, called vascular markings, which are most conspicuous near the median parts of the border, where the latter attains the greatest elevation. Several ridges, limiting vascular grooves, extend posteriorly as far as the anterior border of the muscular area. The space between the muscular area and the thickened border is marked by small ovarian pits.

In other specimens of the same general appearance, the alternation of more prominent striae with sets of three finer striae is shown best by the pedicel valve, but a similar tendency is shown also along the postero-lateral angles of the brachial valve and over the flattened umbonal area. Anteriorly, on the deflected marginal portion, the striae are coarser, and either alternating in size or approximately subequal. About 13 striae occupy a width of 5 mm. Some specimens are fully mature when they have reached a width of only 20 mm., while others attain a width of 25 mm., a length of 21 mm., and a convexity of 10 mm. The thickened border along the interior of the pedicel valve may reach a height of 10 mm., measured from the anterior margin of

the valve. The ovarian pits usually are conspicuous only on the posterior part of the pedicel valve. Occasionally the shell is slightly extended at the hinge-line. The brachial valve, of course, presents a similar outline. The impression of the adductor muscles usually is deep, and strongly defined by the callosity bordering the anterior part of the crural plates and the cardinal process. There is a strong medial elevation, separating the adductor scars, anterior to which are the median ridges separating the vascular grooves.

While it is evident that the smaller specimens, described in the preceding lines, are to be regarded as the types of *Strophomena nutans,* it must be remembered that they are gerontic individuals secured by selection from a much larger series, in which the callosity along the interior border of the pedicel valve is much less conspicuous, and which frequently attain a much larger size. Some of these larger specimens, occurring in the same slabs of rock, for instance in the Rocky Hollow northwest of Clarksville, Ohio, attain a width of 32 mm. a length of 25 mm., with a convexity of 14 mm. In all of these larger specimens, the thickening along the interior border of the pedicel valve is much less conspicuous, not exceeding a height of 5 mm. above the plane passing through the margins of the valve, or a height of 6 mm., measured along the slope of this border. Moreover, this thickened border is less distinctly limited on the posterior side, and the transverse radial vascular grooves extend farther toward the muscular area. In still other shells, from the same layers, the thickening along the border becomes slight, and the shallow, radial vascular grooves are inconspicuous. Shells of this type closely resemble *Strophomena concordensis,* from the top of the Arnheim, and some individuals could scarcely be distinguished from the latter if their origin were not known. In fact, the smaller, typical specimens of *Strophomena nutans* are regarded as the retarded, gerontic forms of *Strophomena concordensis.* Fig. 1 *d,* accompanying the original description of this species by Meek, may represent the interior of the brachial valve of one of these larger forms associated with the smaller, narrower, and more typical forms of *Strophomena nutans.* (Plate X, Fig. 3.)

Where abundant material is at hand, there is no difficulty in distinguishing between *Strophomena nutans* and *Strophomena con-*

cordensis. *Strophomena nutans* occupies a later horizon and may be regarded as a direct derivative of the *Strophomena concordensis*.

At Clarksville, in Clinton county, unquestionably one of the type localities, the range of *Strophomena nutans* begins 12 feet above the lower *Hebertella insculpta* horizon, in the Blanchester division of the Waynesville bed.

Hebertella insculpta occurs at several horizons in Cincinnatian areas: at the base of the upper or Blanchester division of the Waynesville; from 25 to 40 feet higher, at the base of the Liberty bed; and at a third horizon, between 15 and 20 feet above the base of the Liberty.

At the base of the Blanchester division, *Hebertella insculpta* is distributed throughout Ohio, from Eagle Creek, about 5 miles west of West Union, in Adams county, to the vicinity of Oxford, in the northwestern part of Butler county. At the base of the Liberty bed, it extends from Wyoming, in the southern part of Fleming county, Kentucky, throughout Ohio, to Madison, in Jefferson county, Indiana. At the third horizon, between 15 and 20 feet above the base of the Liberty, it is known east of Weisburg, in the northwestern part of Dearborn county, and 1 mile north of Brownsville, in Union county, Indiana. The vertical and geographical distribution of *Herbertella insculpta* in this lower part of the Liberty member requires further study. Two miles east of Cross Plains, in the southeastern corner of Ripley county, a few specimens of *Hebertella insculpta* occur near the base of the *Dinorthis subquadrata* zone, the latter being separated from the top of the main *Hebertella insculpta* horizon, 5 feet thick, which occurs at the base of the Liberty, by an interval of $3\frac{1}{2}$ feet.

The lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville, introduces a new Richmond fauna. Here, or immediately above this horizon, *Dinorthis carleyi* makes its second appearance, and *Catazyga headi* comes in.

Strophomena nutans and *Strophomena neglecta* make their first appearance usually between 7 and 12 feet above the lower *Hebertella insculpta* horizon. *Strophomena vetusta-precursor* usually comes in later than the other two species, although commonly before the disappearance of *Strophomena neglecta*. Frequently *Strophomena vetusta-precursor* continues later than *Strophomena*

neglecta, and occasionally *Strophomena nutans* is seen earlier than *Strophomena neglecta*, so that the order of succession becomes *Strophomena nutans*, *Strophomena neglecta*, *Strophomena vetusta-precursor*, with the range of *Strophomena neglecta* overlapping that of the two other species.

At Moores Hill, Indiana, and at Oxford and Oregonia, Ohio, the total thickness of this *Strophomena* section, at the middle of the Blanchester division, including the three species named, equals about 12 feet. At Jacksonsburg and Clarksville, Ohio, it equals 8 feet. At Canaan, in the northern part of Jefferson county, Indiana, in Adams county, Ohio, and at Concord, Kentucky, it equals only 3 or 4 feet. At Moores Hill, and Weisburg, Indiana, and at Oregonia and Clarksville, Ohio, the top of this *Strophomena* section extends to within 5 or 6 feet from the base of the upper *Hebertella insculpta* zone, which forms the base of the Liberty bed. Where the *Strophomena* section is limited to only several feet, its distance from the upper *Hebertella insculpta* horizon may equal 10 to 15 feet.

The greatest vertical range of *Strophomena nutans* usually does not exceed 2 or 3 feet, but occasionally equals 7 feet.

The geographical range of *Strophomena nutans* extends from the southwestern part of Adams county, 2 miles northeast of Bradyville; northward as far as the Narrows, east of the Pinnacles, 4 miles southwest of Dayton, Ohio; westward to the northern edge of Union county, a mile and a half south of Abingdon, Indiana, and southward to Moores Hill, also in Indiana.

Fig. 2 *B*, on plate III of this Bulletin, presents a view of a specimen of *Strophomena*, somewhat resembling *Strophomena nutans*, from the Whitewater beds at Tate Hill, east of the Focke slaughter house, on the Springfield pike, in the eastern part of Dayton, Ohio. The thickened anterior border ascends vertically a distance of 7 mm. The presence of a similar outline and of a similar considerable thickening of the interior border of the pedicel valve may not be indicative of any direct relationship of this shell to *Strophomena nutans*. Similar conditions may give rise to similar forms at different times without predicating a similar line of descent.

A fragment of *Strophomena*, resembling *Strophomena nutans*, was found 3 miles north of Wekwemikongsing, on the eastern shore of Manitoulin Island (plate XI, Fig. 8).

Strophomena planumbona, Hall[9]

(Plate VIII, Figs. 1 A, B, C, D, E; Plate IX, Figs. 3 A, B; Plate IV, Figs. 1, 2, 3, 4; Figs. 3 A, B, are typical)

The types of *Strophomena planumbona,* numbered 918–3, are preserved in the American Museum of Natural History in New York City. They are labelled as coming from Cincinnati, Ohio, but the species occurs only at horizons belonging stratigraphically above the highest beds exposed at Cincinnati. In the original description the localities mentioned are Cincinnati and Oxford (Ohio), Madison (Indiana), and Maysville (Kentucky). The species does not occur at Cincinnati, although specimens have been sent out by Cincinnati collectors to many museums in this country and in Europe. The specimens found at Maysville, Kentucky, here are described as *Strophomena concordensis.* At Oxford, Ohio, and Madison, Indiana, *Strophomena planumbona* is common in the Clarksville and Blanchester divisions of the Waynesville bed. Lithologically, the types closely resemble specimens of this species collected at Madison, Indiana, but their exact origin is unknown. Undoubtedly they were obtained from the Waynesville bed.

Fig. 4 *a,* on plate 31 *B, New York Paleontology,* vol. I, represents the pedicel valve. The specimen is entire, presenting both valves. The chief feature of the pedicel valve is the presence of distinctly stronger striae, separated by much finer striae, usually three in number. Anterior to the middle of the shell, the middle one of the group of finer striae frequently becomes more conspicuous, and additional finer striae come in, preserving the appearance of stronger striae, each pair being separated by several finer striae. The tendency toward the alternation of single stronger striae with two or three distinctly finer striae is shown also by the brachial valve, especially along the lateral margins, and over the flattened portions of the valve as far anterior to the hinge-line as the area where the more rapid downward curvature of the shell begins. Along the anterior parts of the brachial valve, there is a tendency toward an alternation between single stronger and single finer striae. In slightly weathered specimens, in which the intermediate finer striae are not readily

[9] *New York Paleontology,* vol. i, p. 112, 1847.

detected, the anterior parts of the shell appear ornamented by rather distant stronger striae of which 8 or 9 may appear in a width of 5 mm.

On the brachial valve represented by Fig. 4 *b*, the striae along the anterior margin are more nearly subequal, owing to the increase in size of the intermediate finer striae anteriorly, and here about 15 or 16 striae are noted in a width of 5 mm.

In the specimen represented by Fig. 4 *a*, the length is 20 mm.; the width, 25 mm.; and the convexity, about 6 mm. In the specimen represented by Fig. 4 *b*, this convexity equals 7 mm., and in the most gerontic specimens it may attain even 11 mm. The shells have a distinctly quadrate outline, a very slight contraction in width immediately anterior to the hinge-line being balanced by a slight elongation at the hinge-line itself. The brachial valve is distinctly flattened for a distance varying from 12 to 14 mm. anterior to the hinge-line. The concavity immediately anterior to the beak is slight. The hinge-area is rather high, considering the width of the shell, and diminishes rather gradually until near the postero-lateral angles of the shell. In specimen 4 *a*, the height of the hinge-area is 3.3 mm. at the beak; in specimen 4 *b*, it is 3 mm.

In general, the shells of *Strophomena planumbona* are small or attain only medium size. The posterior third of the brachial valve is strongly flattened. Surface striae, fine and thread-like, about 13 in a width of 5 mm.; occasionally as few as 11, rarely as many as 20. Muscular scars of the pedicel valve, producing a circular, deeply impressed area, bordered on each side by a curved, sharply elevated ridge, deflected slightly anteriorly, producing an anterior median gap. Median vascular markings often distinct. The interiors of the pedicel valves are thickened toward the anterior and lateral margins, this thickening often being rather distinctly defined posteriorly, and crossed by branching vascular grooves. Along the sides of the pedicel valves, this interior thickening becomes narrower, though still fairly distinct and showing vascular markings.

In Stony Hollow, northwest of Clarksville, in Clinton county, Ohio, *Strophomena planumbona* makes its first appearance 1 foot above the 5-foot clay layer in which *Orthoceras fosteri* is common. It therefore begins at the base of the Clarksville division, and from this level it continues through the Clarksville

division to the base of the lower *Hebertella insculpta* horizon. The specimens are quadrate in outline, and the radiating striae are subequal in size, or alternately larger and smaller. As a matter of fact, the variety *Strophomena elongata* is more common in the Clarksville bed, at this locality, than the more typical *Strophomena planumbona*, which has a shorter hinge-line. It is evident that *Strophomena planumbona* is connected with *Strophomena elongata* by specimens in which the postero-lateral angles are only moderately acute. Specimens of this type become common in the upper part of the Blanchester division and in the lower half of the Liberty.

No *Strophomenas* occur in the lower part of the Blanchester division. Specimens of *Strophomena planumbona*, with a quadrate outline, come in at the same horizon as the first specimens of *Strophomena nutans* and *Strophomena neglecta*. Near the middle of the Blanchester division, some of these quadrate forms have a rather high hinge-area, considering the size of the shell, with a corresponding increase of the size of the cavity enclosed between the two valves. Moreover, some of the specimens have the alternation of three finer striae with single larger striations, which is characteristic of the type of *Strophomena planumbona*. In fact, it is probable that the types of *Strophomena planumbona* were secured from the upper half of the Blanchester division of the Waynesville member. In some of these specimens, the alternation of three finer striae with a single stronger striation does not continue as far as the anterior margin of the shell, the striae on the deflected anterior slopes being more nearly subequal.

Specimens of *Strophomena planumbona*, with a quadrate outline and with subequal radiating striae, occur also in the Liberty. Here they are associated, however, with more numerous specimens in which the postero-lateral angles are more acute, and in which the oblique wrinkling, characteristic of the type of *Strophomena subtenta*, is seen more frequently. In fact, it is probable that the type of *Strophomena subtenta* was obtained from the lower part of the Liberty. Similar specimens occur in the upper part of the Blanchester division, but in these the oblique wrinkling is much rarer. As a matter of fact, the oblique wrinkling occurs occasionally even in the quadrate forms of *Strophomena planumbona* found in the upper part of the Blanchester division.

Specimens with a successive alternation of three finer radiating striae with a single stronger striation occur also among the forms with moderately acute postero-lateral angles, which are found in the lower Liberty.

It is possible that *Strophomena planumbona* ranges up into the Whitewater bed. There is no doubt that *Strophomena vetusta* is the predominating species in the Whitewater section, and occurs here almost to the exclusion of other forms, but occasionally specimens are found which resemble *Strophomena planumbona* so much that the presence of the latter species in the Whitewater member can not be denied without further investigation.

Strophomena planumbona and *Strophomena subtenta* were described by Hall in vol. I, of the *New York Paleontology*. Since *Strophomena planumbona* was described on an earlier page, this name should be adopted for both forms if *Strophomena subtenta* proves not to be distinct.

The types of these forms are readily distinguishable. In *Strophomena planumbona*, there is a repeated alternation of three finer striae with a single more prominent one. In the type of *Strophomena subtenta*, on the contrary, the radiating striae are more nearly subequal. The type of *Strophomena subtenta*, moreover, is obliquely wrinkled along the hinge-line.

An attempt to distinguish these forms in the field, however, where the specimens are very numerous, fails to substantiate the distinctness between these two supposed species. It is evident, for instance, that the oblique wrinkling, in *Strophomena subtenta*, is conspicuous only in selected specimens, and that it is entirely absent in the majority of specimens which must be referred to *Strophomena subtenta*, since they occur in the same layers and have the same exterior and interior markings, excepting only the presence of the oblique wrinkling along the hinge-line. Moreover, it is not possible to distinguish between *Strophomena planumbona* and *Strophomena subtenta* on the basis of the exterior markings. In the great majority of specimens, the radiating striae are subequal in size, or are alternately larger and smaller. Specimens in which three finer striae alternate repeatedly with a single stronger striation are rather few in number and occur associated with the former in such a manner that it is very evident that they represent only individuals belonging to the same species, and not even a distinct variety.

The first appearance of *Strophomena planumbona*, in Cincinnatian areas, appears to have been about 1 or 2 feet above the *Orthoceras fosteri* horizon, a clay section which, in Clinton and neighboring counties, in Ohio, immediately underlies the middle or Clarksville division of the Waynesville. *Strophomena planumbona* occurs at this horizon at Clarksville, in Clinton county; and at Fort Ancient, Oregonia, and 1½ miles south of Mount Holly, in Warren county. This probably is the horizon of the first specimens along Bush Run, 1 mile northeast of Somerville, in the southern edge of Preble county; and the first specimens seen in the section along the stream east of Moores Hill, in Dearborn county, Indiana. The first specimens seen at Concord, in Lewis county, and at Sunset and Wyoming, in Fleming county, Kentucky, probably belong in the upper part of the Clarksville division. In fact, *Strophomena planumbona* is widely distributed in the upper part of this division, and becomes abundant at certain horizons in the Blanchester division, and in the Liberty member.

At Concord, in Lewis county, Kentucky, and at Sunset, in Fleming county, *Strophomena planumbona* occurs as low as 27 feet below the base of the Liberty. At Wyoming, in Fleming county, it is found 22 feet below the Liberty. At Owingsville, in Bath county, it occurs immediately below the *Strophomena neglecta* horizon, 16 feet below the lowest *Dinorthis subquadrata* specimens.

Along the pike, east of Howards Mill, in Montgomery county, *Strophomena planumbona*, perhaps accompanied by *Strophomena vetusta*, occurs 52 feet below the Clinton. Half a mile west of Spencer, in the same county, *Strophomena planumbona*, also possibly accompanied by *Strophomena vetusta*, occurs 48 feet below the Clinton. A mile and a half northwest of Indian Fields, in Clark county, *Strophomena vetusta* occurs 55 feet below the Clinton, and *Strophomena planumbona*, associated with *Rhynchotrema capax*, ranges from 10 to 18 feet lower. At Merritts Ferry, at the mouth of the Red River, in the southern edge of Clark county, the layer containing *Tetradium*, *Stromatocerium*, and *Columnaria* occurs 90 feet below the Clinton. North of Ophelia, 4 miles north of Richmond, in Madison county, the additional presence, at the same horizon, of *Calapoecia*, and *Beatricea*, associated with *Strophomena planumbona*, *Rhynchotrema capax*,

Streptelasma canadensis, and other fossils, suggests a probable equivalency of this coral horizon to a similar assemblage of fossils at the base of the fossiliferous section beneath the Saluda horizon, in Jefferson, Bullitt, Nelson, Washington, and Marion counties, in the more western part of Kentucky. This horizon is regarded as belonging at the base of the Liberty section.

The statigraphical position of the specimens of *Strophomena* at Howards Mill, Spencer, and Indian Fields, is regarded as at least as high as the middle of the Blanchester division of the Waynesville. Owing to the fact that southward the vertical distribution of the more characteristic Richmond brachiopoda becomes rapidly restricted, until at Owingsville it is confined to the basal part of the Liberty and the upper half of the Blanchester, it is assumed that this is the horizon most likely to furnish fossils farther southward, in Montgomery and Clark counties. At Owingsville, *Dinorthis subquadrata*, *Rhynchotrema capax*, and *Streptelasma canadensis* occupy a horizon 3½ feet thick. *Leptaena rhomboidalis* and *Plectambonites sericea* occupy a section 1½ feet thick, immediately beneath, and are regarded as forming the base of the Liberty here, the *Hebertella insculpta* layer being absent. *Strophomena neglecta* and *Strophomena vetusta* range from 10 to 11 feet below the top of the Waynesville, and *Strophomena planumbona* occurs half a foot lower. As a matter of fact, the *Strophomena* horizons in Montgomery and Clark counties may belong even as high as the upper Liberty. In the absence of fossils distinctly diagnostic of the Liberty or of the Waynesville, an element of uncertainty must remain.

Since at Merritts Ferry the layer with *Tetradium*, *Stromatocerium* and *Columnaria* occurs 90 feet below the Clinton, it is probable that the horizon in the northeastern part of Madison county, 1 mile east of College Hill, containing poor specimens of *Strophomena* and *Streptelasma*, 93 feet below the Clinton, belongs to the same horizon, namely, the base of the Liberty. *Strophomena sulcata* ranges at the same locality from 31 to 40 feet beneath the Clinton, in strata regarded as equivalent to the Whitewater. At Cobb Ferry, nearly 3 miles southeast of College Hill, *Strophomena vetusta* and *Streptelasma canadensis* occur between 54 and 63 feet below the Clinton, and *Streptelasma canadensis* ranges about 5 feet lower. This also should belong to the Liberty horizon.

The horizon with *Tetradium* and *Columnaria* may be traced as far southward as the hill east of the Preachersville pike, 4 miles southeast of Lancaster, in Garrard county, where it is 70 feet below the Clinton, and to various localities east of Rowland, in the northeastern part of Lincoln county, where it is about the same distance below.

In all of the preceding cases, the term Clinton implies the Brassfield member at the base of the Silurian of Kentucky, and not the equivalent of the typical Clinton of New York, which finds its representative in the Crab Orchard section of Kentucky, and in the immediately overlying West Union member.

On the western side of the Cincinnati geanticline, a similar restriction in the vertical range of the brachiopod fauna of the Richmond takes place. At Madison, in Jefferson county, Indiana, and at Milton, on the opposite side of the river, in Kentucky, the lowest specimens of *Dinorthis subquadrata* occur about 75 feet below the base of the Clinton, and *Hebertella insculpta* is found about 7 or 8 feet lower, at the base of the Liberty bed. *Strophomena planumbona* occurs in the lower part of the Liberty, and also in the upper part of the Waynesville, the lowest specimens being found 30 feet below the lowest specimens of *Dinorthis subquadrata*. At the mouth of Bull Creek, in Clark county, Indiana, the lowest specimens of *Dinorthis subquadrata* occur 63 feet below the Clinton, and only the upper 20 feet of the Waynesville bed are richly fossiliferous, containing *Strophomena elongata* and *Strophomena planumbona*. *Zygospira kentuckiensis* occupies the underlying part of the section, 8 feet thick, and *Tetradium* is abundant from 8 to 12 feet lower.

About 5 miles south of the mouth of Bull Creek, 2 miles northwest of Brownsboro, in Oldham county, the lowest specimens of *Dinorthis subquadrata* occur 60 feet below the Clinton. *Strophomena vetusta* occurs in the overlying part of the Liberty section, 12 feet thick, but no species of *Strophomena* was noted in the underlying fossiliferous section, the upper part of the Waynesville. Along the railroad from Jeffersontown eastward to Fisherville, in the eastern part of Jefferson county, in Kentucky, a conspicuous *Columnaria vacua* horizon is found below the richly fossiliferous Liberty section, which there includes *Strophomena vetusta*, *Dinorthis subquadrata*, and, near the base, also *Strophomena planumbona*. Specimens of *Strophomena planum-*

bona-elongata occur about 13 feet below this *Columnaria* horizon, in the upper Waynesville. South of Jefferson county, *Strophomena planumbona* is known, in the Waynesville, only from the strata immediately beneath the *Columnaria* horizon, the most southern occurrence known in Kentucky being about 4 miles north of Bardstown.

Specimens closely similar to *Strophomena planumbona* occur in the Waynesville division of the Richmond at Dismukes Station, 4 miles north of Gallatin, in Tennessee.

The fossiliferous part of the Liberty section also thins out southward. The most southern localities for *Dinorthis subquadrata* are at Bardstown, and on Mill Creek, 4 miles east of Bardstown. At these localities *Dinorthis subquadrata* is associated with *Strophomena vetusta*, no specimens of *Strophomena planumbona* having been found. The most southern localities for *Strophomena planumbona* in the Liberty are in the vicinity of Mount Washington, in Bullitt county, where they occur only in the basal part of the Liberty, immediately over the *Columnaria* horizon. Northward, in Indiana and Ohio, *Strophomena planumbona*, especially the variety *Strophomena subtenta*, is very abundant in the Liberty, especially its lower half.

The richly fossiliferous horizon at the base of the Liberty may be traced as far south as Raywick, in the western part of Marion county, but the only species of *Strophomena* seen here is *Strophomena sulcata*.

Strophomena planumbona is known also from the southern base of Jeptha Knob, in the eastern part of Shelby county, a short distance south of J. P. Wellman's barn. Farther southward, *Strophomena vetusta* is seen. Both exposures probably belong to the Liberty horizon, although no specimens of *Dinorthis subquadrata* were found.

It is doubtful whether *Strophomena planumbona* occurs in the Whitewater bed. Interiors of pedicel valves suggesting the presence of *Strophomena planumbona* are seen in the Whitewater member at several localities near Dayton, Ohio, but the exteriors as well as the interiors of these valves must be seen, in order to distinguish between some specimens of *Strophomena vetusta* and some of *Strophomena planumbona*. At any rate, *Strophomena vetusta* is very abundant in the Whitewater, and while *Strophomena planumbona* may be present occasionally, it certainly must occur only as occasional or sporadic specimens.

Judging from the fact that *Strophomena planumbona* makes its appearance earlier in the Waynesville section in Ohio and Indiana than southward in Kentucky, it is regarded as another of the species having a northern or northwestern origin as far as the immediate territory under consideration is concerned. It evidently is closely related to species distributed from Illinois southward as far as southern Tennessee. The connection with this western basin, however, appears to have been by way of northern Illinois rather than by means of some more southern channel. This leaves the general question as to the origin of the Mississippi Valley Richmond entirely untouched.

Strophomena planumbona-elongata, James[10]

(Plate IV, Figs. 1 A–L; Plate IX, Figs. 4 A, B)

The types of *Strophomena elongata*, James, numbered 510, are preserved in the James collection, in the Walker Museum, at Chicago University.

The types present the following characteristics. General outline of the shell broadly semicircular, elongate along the hinge-line. Angle between the general lateral outline and the hinge-line between 60 and 70 degrees. Brachial valve convex, especially from front to rear; the transverse section much less convex, moderately flattened toward the beak, especially over an area extending 8 to 10 mm. from the posterior margin. Usually an almost imperceptible median depression extends forward from the beak about 6 or 7 mm. Radiating striae of the brachial valve subequal and of medium size, about 14 or 15 in a width of 5 mm. Radiating striae of pedicel valve slightly finer, about 16 or 17 or 18 in a width of 5 mm. at 20 mm. from the beak. Greatest convexity of the pedicel valve near the middle or slightly anterior. Hinge-area of medium height, narrowing toward the extremities, equalling 2.8 mm. at the beak.

Width of one of the type specimens, 35 mm.; length 22 mm.; convexity at 11 mm. from the beak, 8 mm. Length of the hinge-area, 34 mm.; height at the beak, 2.8 mm. Maximum convexity of the hinge-area, observed among other type specimens, 4.4 mm., in a shell 38 mm. wide along the hinge-line, 23.5 mm. long, and with a convexity of 13 mm. This was a very obese specimen.

[10] *Cincinnati Quarterly Journal of Science*, vol. i, p. 240, 1874.

Figs. 4, *A*, *B*, on plate IX of this Bulletin present posterior and lateral outlines of the type from the James collection which is illustrated by Fig. 1, *I* on plate IV.

Strophomena elongata differs from typical examples of *Strophomena planumbona* chiefly in its greater width along the hinge-line and in its much greater convexity from front to rear. The shells frequently attain a width of 40 mm. along the hinge-line, and the postero-lateral angles often reach 70 degrees. Not all the shells have acute postero-lateral angles. Some specimens have considerable width compared with the length, but the angles at the hinge-line are almost rectangular. In some specimens the ratio of width to length is as seven to four. The specimens with acute postero-lateral angles and with strongly convex brachial valves have a subtriangular appearance, but there is a tendency toward a flattening of the antero-lateral slopes, the anterior outline remaining more or less evenly rounded. The convexity from front to rear frequently equals half the length. In the original description the shell is stated to narrow rapidly to the front, giving it a triangular outline. It is evident from the types that this statement is exaggerated and misleading.

The muscular area of the pedicel valve is broadly oval. It is deeply impressed, the lateral borders are prominent and sharp, being deflected toward the front anteriorly, leaving a median gap. A low median ridge, sometimes bordered on each side by a narrow, linear area representing the adductors, divides the muscular area. On each side of this area the inner surface of the valve not infrequently is pitted or covered with low elongate papillae, usually interpreted as ovarian markings. The inner margin of the shell is thickened, especially anteriorly, and this thickening is crossed more or less radially by vascular markings, which may be traced a short distance toward the muscular area.

Owing to the considerable convexity of the brachial valve, the interior surface appears deeply concave. The adductor muscle areas are deeply impressed posteriorly, and sometimes distinctly limited also anteriorly, but usually several radial ridges, probably to be interpreted as vascular markings, cross the anterior outline. The two inner ridges of this set are extended anteriorly along the median part of the valve. The crural ridges are prominent and limit the adductor areas posteriorly. A broad ridge extends forward from the callosity anterior to the cardinal process.

Specimens of this type are common in the middle or Clarksville division of the Waynesville bed, but they occur also in the upper or Blanchester division. Not infrequently they are wrinkled obliquely along the hinge-line. As a rule, the radiating surface striae alternate moderately in size or are approximately equal.

The vertical and geographical range of the variety of *Strophomena planumbona* which was described by James as *Strophomena elongata* is very imperfectly known. No attempt has been made so far to determine whether it has any value as a diagnostic fossil, characteristic of some definite horizon.

In Stony Hollow, northwest of Clarksville, in Clinton county, Ohio, *Strophomena elongata* makes its appearance 1 foot above the base of the Clarksville division of the Waynesville member, or 1 foot above the top of the 5-foot clay section in which *Orthoceras fosteri* is common. From this horizon, *Strophomena elongata* ranges throughout the Clarksville division, occurring as far up as the lowest layers belonging to the lower *Hebertella insculpta* horizon. Throughout this Clarksville division, the radiating striations usually are subequal in size, or alternately larger and smaller. Specimens in which 3 finer striae occur between each pair of stronger striations are found, but are not common and are not characteristic of this variety.

No species of *Strophomena* is found in the lower half of the Blanchester division of the Waynesville member, between the lower *Hebertella insculpta* horizon and the lowest horizon at which *Strophomena nutans* and *Strophomena neglecta* make their appearance. This is an interval of 12 feet.

The more quadrate forms of *Strophomena planumbona*, which are present also throughout the Clarksville division, reappear at the lowest horizon containing *Strophomena nutans* and *Strophomena neglecta*, and continue to the top of the Waynesville member, and beyond the middle of the Liberty. The variety known as *Strophomena elongata*, however, appears to be represented only by a few, not very typical, specimens near the base of the upper *Hebertella insculpta* horizon, in the upper part of the Blanchester division of the Waynesville.

Along the Stony Brook, 1 mile southeast of Fort Ancient, in Warren county, Ohio, typical *Strophomena elongata* also occurs in the Clarksville division, making its first appearance 2 feet

above the *Orthoceras fosteri* layer. It probably occurs in the Clarksville division also at Wyoming, in the southern part of Fleming county, where *Strophomena elongata* is found 9 feet below the *Strophomena neglecta* horizon. At Sunset, in the same county, *Strophomena elongata* occurs at various levels within 12 feet of the base of the upper *Hebertella insculpta* horizon, in the upper or Blanchester division of the Waynesville. It appears to occur in the Blanchester division, or its equivalent, also along Silver Creek, northeast of Dunlapsville, in Union county, Indiana; at Moores Hill, in Dearborn county; at Madison, in Jefferson county; and at the mouth of Bull Creek, in Clark county. East of Jeffersontown, in the eastern part of Jefferson county, Kentucky, *Strophomena elongata* occurs 13 feet below the *Columnaria* horizon, in strata regarded as upper Waynesville.

These data suggest a range from the lower Clarksville to the top of the Blanchester, with a gap in the lower half of the Blanchester.

Strophomena planumbona-subtenta, Hall[11]

(*Plate IV, Figs. 4, A, B, C, D; Plate VIII, Figs. 2 A, B; Plate IX, Fig. 2*)

The name *Strophomena subtenta* was first published by Conrad, in the *Fifth Annual Report of the New York Geological Survey*, in 1841, on page 37, but no description of the species was given until Prof. James Hall published his report in the *New York Paleontology*, vol. 1, in 1847. On page 115 of this volume, Professor Hall stated:

> I find among the drawings of Mr. Conrad, the figure of a Trenton species, with this name attached. I have not seen the same in New York, but the specimen figured is from a western locality. It bears all the essential marks of the species cited, and I have therefore introduced it under that name. The strong oblique wrinkles form a distinguishing feature.
>
> *Position and locality.* In the Blue limestone of Ohio, associated with *Leptaena alternata, Leptaena sericea*, and *Orthis testudinaria*. Oxford (Ohio). Trenton Falls, on the authority of Mr. Conrad.

From these notes it is evident that the specimen figured by Hall on plate 31 *B* as *Leptaena subtenta* is the same specimen

[11] *Strophomena subtenta*, Hall, *New York Palentology*, vol. i, p. 115, 1847. *Strophomena plicata*, Meek, *Ohio Paleontology*, vol. i, p. 81, 1873.

as that figured by Conrad and accompanying his unpublished manuscript.

The type of *Strophomena subtenta*, numbered 922–2, is preserved in the American Museum of Natural History, in New York City. It is a brachial valve, 19 mm. in length, 26 mm. in width, and 5 mm. in convexity. The concavity anterior to the beak is slight, and the flattening of the posterior parts of the valve scarcely extends farther than 11 mm. from the posterior margin of the shell. The divergent wrinkles along the hinge-line are distinctly defined. The postero-lateral angles of the shell are essentially rectangular, but rounded at the apices of the angles. The surface striae are subequal in size, and vary from 5 to 7 in a width of 2 mm. along the anterior margin of the shell, the first number being more nearly typical. Unfortunately the type specimen does not present the surface features of the pedicel valve, but other specimens show that the surface striae of the latter also are subequal in size, but are slightly finer than those in the brachial valve.

A comparison of the type of *Strophomena subtenta* with those of *Strophomena planumbona* suggests that the former might be distinguished from the latter by the oblique wrinkling along the hinge-line and by the subequal surface striae. As a matter of fact, however, the oblique wrinkling is soon found, in the field, to be an individual characteristic, not uncommon in the individuals at some localities, for instance at Concord, Kentucky, but practically absent at other localities at the same horizon. In the same manner, the subequal size of the surface striae has been found to be an unreliable feature, specimens possessing these characteristics grading into others in which every third or fourth striation is more prominent.

After having repeatedly seen the types of *Strophomena planumbona* and *Strophomena subtenta*, and having had them several times in my possession, owing to the courtesy of Professor Whitfield and Dr. Hovey, I spent several days at Clarksville, at Oregonia, and along the creek south of Jacksonburg, northwest of Trenton, Ohio, and elsewhere, localities at which it was possible to secure specimens from every foot of the section, in order to learn if it might not be possible to make at least some use of *Strophomena subtenta* as a variety characterizing some horizon, but without success. The best that can be said is that typical

specimens of *Strophomena subtenta*, with the oblique wrinkles and subequal striae, were found more frequently in the lower part of the Liberty, for instance at Concord, Kentucky; at Clarksville, near Dayton, west of Camden, and near Oxford, Ohio; also at Richmond, and thence southward to the mouth of Bull Creek, in Indiana. While especially common in the lower half of the Liberty bed, it is found also in the upper half of the Blanchester, and in the Clarksville division, its range being coterminous with that of typical *Strophomena planumbona*. In the other direction, upward, it is found as high as the top of the Liberty.

Among specimens of *Strophomena planumbona* without the oblique wrinkles, there is every variation at the same horizon from subequal striae to those with every second or fourth striation distinctly more prominent. Moreover, the oblique wrinkling occurs both in the subequally and in the unequally striated shells, so that it has been found impossible to make use of either feature or of both combined in the discrimination of *Strophomena subtenta* from *Strophomena planumbona* in the field, not from selected specimens.

The type of *Strophomena subtenta* came from the vicinity of Oxford, Ohio. While *Dalmanella jugosa* (*Orthis testudinaria* of Hall) is common in the Fort Ancient and Clarksville divisions of the Waynesville bed, and practically is absent above the middle of the Blanchester division, it by no means follows that the type of *Strophomena subtenta* came from the Clarksville division of the Waynesville. At the time of the original description of that species, the various horizons of the Cincinnatian fossils were not as carefully discriminated as later, and the fact that *Strophomena subtenta* occurred in the same general neighborhood as *Dalmanella jugosa* might have been considered sufficient to regard them as associated.

While the exact horizon from which the type of *Strophomena subtenta* was obtained is somewhat in doubt, there is no uncertainty about that of *Strophomena plicata*, Meek, since no strata below the Liberty are exposed near the base of the hills at Richmond, Indiana. The nearest exposure of the upper *Hebertella insculpta* horizon, at the base of the Liberty, below the lowest exposures containing *Dinorthis subquadrata*, occurs 4 miles down the river, from Richmond, a quarter of a mile east of the mouth of the Elkhorn Creek, in the lowest exposures on that stream.

Plectambonites sericea has a considerable range in the Liberty bed, not only in Wayne county, in Indiana, but also in Preble county, Ohio, and in the adjacent counties, and must be used with care in determining the base of the Liberty. It is the second great influx of *Hebertella insculpta*, followed this time in close succession by *Dinorthis subquadrata*, which marks the base of the Liberty.

Strophomena planumbona-gerontica, var. nov.

(*Plate IV, Figs. 2 A, B, C; Plate XI, Fig. 6*)

One of the extreme variations of *Strophomena planumbona* is remarkable for its decidedly gerontic appearance. The shells are rather small and very thick. The brachial valves are strongly convex. The hinge-area of the pedicel valve is distinctly higher along its entire length than in ordinary specimens of this species. The general outline of the shell is semicircular, or subquadrate. The length usually varies between 26 and 33 mm. The ratio of the length to the width along the hinge-line varies from 0.87 to 0.68. The ratio between the depth or greatest convexity of the shell and its length usually varies between 0.50 and 0.58. The gerontic character frequently is indicated by numerous lines of growth near the anterior margin of the shell, the shell having increased greatly in thickness without any proportionate increase in length.

Shells of this description occur in the Blanchester division of the Waynesville bed, near Clarksville, and Oregonia, Ohio, and near Roseburg, at Madison, and at the mouth of Bull Creek, in Indiana. A similar individual was found near the top of the bluff directly west of the wharf at Gore Bay, on Manitoulin Island (plate XI, Fig. 6).

Strophomena rugosa, Blainville

The following description of *Strophomena rugosa* was published by H. M. Ducrotay de Blainville in his *Manuel de Malacologie et de Conchiologie*, page 513, in 1825:

> Animal tout-a-fait inconnu.
>
> Coquille régulière symétrique, equilaterale, sub-equivalve; une valve plate et l'autre un peu excavée; articulation droite, transverse, offrant

à droite et à gauche d'une subéchancrure mediane, une bourrelet peu considérable, crénelé ou dentelé transversement; aucun indice de support.

Ex. *La Strophomene rugueuse, Strophomena rugosa,* Rafin., pl. LIII, fig. 2.

Observ. Ce genre, proposé par M. Rafinesque, ne contient encore que des espèces fossiles, au nombre des trois, suivant M. Defrance.

The following is a free translation:

Animal altogether unknown.

Shell regularly symmetrical, equilateral, with valves nearly equal in size; one valve flat and the other a little concave; hinge line straight, transverse, presenting, on the right and left of a sort of median V-shaped groove (formed by the hinge-areas), a small, moderately prominent elevation (the deltidium and chilidium), having a crenate or dentate outline when examined transversely; no indication of a means of support (pedicel).

The original figures were reproduced by Hall and Clarke in vol. VIII of the *Paleontology of New York,* page 247, in 1892. However, the copy of the pedicel valve presents only 72, instead of 92 radiating striae, and the postero-lateral angles are represented as more rectangular than in the original figure. Moreover, the figure of the brachial valve, showing also the hinge-area and deltidium of the pedicel valve, presents only 63 instead of 94 radiating striae, and fails altogether to show the distinct downward flexure of the marginal parts of the shell for a distance of fully 3 mm. from the anterior margin, and 2½ mm. from the lateral margin of the shell, as far back as the hinge-area, producing a geniculate downward depression of the shell all around the margin, beginning at an elevated concentric wrinkle, which is bordered posteriorly by a moderate concentric depression. The large size of the deltidium of the pedicel valve is brought out by Hall and Clarke's figure, but the lateral outlines of this deltidium are slightly convex instead of slightly concave.

In the *Dictionnaire des Sciences Naturelles,* vol. LI, page 151, published in 1827, Defrance gives the following description:

Strophomene rugueuse; *Strophomenes rugosa,* Rafinesque. Coquille bombée en dessous, et dont la valve supérieure est un peu concave et chargée de petites stries rayonnantes. Largeur, un pouce. Fossile de l'Amérique sèptentrionale. On voit une figure d'une coquille de cette espèce dans l'atlas de ce Dictionnaire, planche des fossiles. Des coquilles de ce genre, qu'on trouve à Dudley en Angleterre, ont de trés-grands rapports avec cette espèce; elles en different pourtant en ce que

le bord de celles d'Amérique se rétrousse un peu en dessous, tandis que c'est le contraire pour celles d'Angleterre, dont le bord s'abaisse en dessous. On trouve à l'ambouchure de la rivière des Alleghanys près de Pittsborough (Amérique septentrionale), dans un gres rougeatre, des empreintes de coquilles qui ont beaucoup de rapports avec cette espèce, mais qui sont plus aplaties.

The following is a free translation:

Shell with lower (brachial) valve convex and with upper (pedicel) valve a little concave, and covered with small radiating striae. Size, an inch. Fossil from North America. A figure of a shell belonging to this species may be seen in the set of plates accompanying this Dictionary, on the plate devoted to the illustration of fossils. The shells found at Dudley in England (*Strophonella euglypha*?) are closely related to this species. They differ chiefly in that the border of the lower valve bends up a little below (when the shell is placed with the brachial valve downward), while the contrary is true of the English specimens, whose border turns downward. (The last statement is not true, if the Dudley shell was *Strophonella euglypha.*) At the mouth of the Allegheny River near Pittsburg, in a reddish sandstone, casts of shells are found (*Derbya*?), which are closely related to this species, but are flatter.

If the interpretation given in the preceding translation is correct, these early writers were impressed more by the presence of a prominent deltidium than by the reversal of curvature of the shell, unless Defrance had some other shell in mind than the common Wenlock species, *Strophonella euglypha.* The chief reason for regarding *Strophomena rugosa* as a shell in which the general curvature of the brachial valve is convex are the figures accompanying the text, rather than the description.

The blunt truth, however, is that when it comes to the identification of the *species* originally described as *Strophomena rugosa,* this is pure guess-work, and the revival of this term, in the absence of any type specimens, or fuller subsequent description, or any knowledge of the locality from which it was obtained, is not to be recommended.

Strophomena neglecta, James[12]

(Plate V, Figs. 1 A, B; 3 A, B, C, D, E, F; Plate VII, Fig. 5; Plate IX, Figs. 1 A, B, C; 10; Plate XI, Fig. 10)

Strophomena neglecta was described by U. P. James from the upper or Blanchester division of the Waynesville bed, at a locality north of Second Creek, reached by going 1 mile west from Blanchester, Ohio, and then half a mile north. The collecting ground is east of the road, along a small branch entering Second Creek from the south. The lower *Hebertella insculpta* layer is exposed at the base of the section.

In the James collection, in the Walker Museum, at Chicago University, a series of specimens, numbered 2393, is labelled as types of *Strophomena neglecta*. Among these is the specimen represented by Figs. 1 *A*, *B*, on plate V, and Figs. 1 *A*, *B*, *C*, on plate IX of this Bulletin. This presents the normal aspect of the shell as far as the fineness and nearly equal size of the radiating striae, and the general curvature of the shell are concerned. The specimen is imperfect, however, anteriorly, and clay was moulded to it before photographing, the line of junction of which may be traced in the figures, especially 1 *B*. As a matter of fact, this attempted restoration was not very successful, and the outline should have been more nearly that shown by the right side of Fig. 3 *F*, on the same plate. It will be noted that in the case of Fig. 3 *F*, the left postero-lateral angle is almost rectangular, and shells with this subquadratic outline predominate. In the original description it was stated that *in some cases* the radiating striae vary *considerably*, and are irregularly arranged, from one to three or four of the smaller being placed between each two of the larger. The language used itself suggests that this type of ornamentation is not normal, as indeed it could not be, since it is characteristic of *Strophomena vetusta-precursor*, a shell occurring at the same horizon as *Strophomena neglecta*, and not recognized as clearly distinct by James, although he had described *Strophomena vetusta* himself, also from the vicinity of Blanchester, seven years earlier. The fact is that a moderate variation in the size of the striae, resulting in a grouping of finer striae among each pair of more prominent ones, is common, and

[12] *Paleontologist*, No. 5, p. 41, 1881.

the shells with the more conspicuous alternation of coarse striae with bundles of three or four finer striae were not readily distinguishable until the interiors of these shells were better known. Moreover *Strophomena vetusta* was established on a group of shells in which the nearly vertical wrinkling along the hinge-area was conspicuous, while in the earlier forms, here called *Strophomena vetusta-precursor,* this wrinkling is not always so conspicuous. Hence some specimens of the latter, for instance the one represented by Figs. 2 *A, B,* on plate V of this Bulletin, also appear among James's types of *Strophomena neglecta.* This has made possible the confusion in the interpretation of *Strophomena neglecta* shown by various authors, but a careful rereading of the original description, by one familiar with the conditions at Blanchester, and knowing the types, will readily verify the conclusion that James never intended to include in his *Strophomena neglecta* the Liberty and Whitewater species, *Strophomena vetusta,* in which the vertical wrinkling along the hinge-line is so characteristic. In reading this description by James, it should be remembered also that the term *Strophomena filitexta* was used by him for the specimens described and figured by Meek as that species, and not for the *Strophomena filitexta* of Hall, a species from a much lower horizon.

The type specimen illustrated by Figs. 1 *A* and *B,* on plate V of this Bulletin, presents the following characteristics. The greatest convexity of the brachial valve is 20 mm. from the beak; the thickness of the shell here is 6.8 mm. The valve is distinctly flattened posteriorly, especially within 15 mm. from the beak. Near the beak, the valve is slightly, but distinctly concave, the greatest concavity being 3 mm. from the beak. Hinge-area of the pedicel valve with a height of 3.8 mm. at the beak. The umbo anterior to the beak is most prominent about 4 mm. from the posterior margin of the shell, the general convexity of this part of the shell extending for about 13 mm. from this margin. Radiating striae of the brachial valve rather fine, every fourth, fifth or sixth stria slightly more prominent, about 13 or 14 striae occurring in a width of 5 mm. at a point 28 mm. from the beak. The striae on the pedicel valve are slightly more numerous and finer.

This specimen is the one referred to by Meek (*Paleontology of Ohio,* vol. I, page 85) when he states that one of the type speci-

mens of *Strophomena neglecta* was much more elongated on the hinge-line, and evidently had more acutely angular lateral extremities. He states, moreover, that all the type specimens have nearly the same sized striae, corroborating the view expressed above, that James did not intend to include shells of the type of *Strophomena vetusta* in his original description of *Strophomena neglecta*.

The muscular area of the pedicel valve of this species is large, forming about two-fifths of the width of the shell at the hinge-line. One of the chief diagnostic characteristics of the species is the presence of a series of radiate markings crossing the muscular area, resulting in a flabellate scar. The muscular area is traversed by a median ridge, which widens along the posterior half and bears the adductor scars. The outline of the muscular area is nearly circular, or sometimes more narrow and elliptical. The exterior edge of the border usually is abruptly elevated above the general surface of the interior of the valve, but the impressed muscular area rises rather gradually toward the anterior part of this border. Occasionally, the border rises only slightly above the general surface of the interior. In this case, the general surface of the interior of the shell is covered by numerous, minute papillae, arranged more or less parallel to the radiating striae seen on the exterior of the shell; and the shell is only slightly thickened toward the border. In specimens having a prominent border limiting the muscular area, the minute papillae are seen chiefly toward the margin of the shell, the parts surrounding the muscular area usually being covered with stronger, more or less radiating markings, which occasionally are broken up into irregular series of elongated papillae, similar to those identified as ovarian markings. The thickening of the shell toward the anterior and lateral margins of the interior usually is not conspicuous.

The interior of the brachial valve is marked by numerous minute papillae, except toward the muscular region, where they become larger. There is a tendency toward the arrangement of these papillae in more or less radiating rows. The adductor scars are distinctly limited posteriorly, but anteriorly their outline is rather vague. A triangular thickened area extends from the cardinal process forward, and then is extended across the adductor area as a low median elevation, disappearing near the anterior edge of the adductor area. The vascular ridges and sinuses,

usually extending forward from the muscular area toward the anterior margin of the shell, are either absent or relatively indistinct. The cardinal process is prominent, extending at right angles from the flattened area anterior to the beak. It is bi-lobed, and each lobe is grooved along the top, the grooves making angles of about 45 degrees with each other.

At the time the original description was published, nothing was known of the interior of the shell, and hence its description was based upon the appearance of the exterior. One of the chief characteristics of this part of the shell consists in the fineness and comparative equality in size of the radiating striae. At a distance of 30 mm. from the beak, the number of these striae varies from 12 to 15 in a width of 5 mm. Fifty millimeters from the beak, their number may equal only 8 or 9 in a width of 5 mm. The radiating striae on the pedicel valve are distinctly finer, compared with the more prominent striae on the brachial valve; in one case there were 15 striae in a width of 5 mm. while on the brachial valve there were 12 in the same width. Occasionally, the striae are distant from each other, and only 9 or 10 may be found in a width of 5 mm. at a distance of 30 mm. from the beak along the median part of the brachial valve. The radiating striae are crossed by much finer concentric striae, which usually are very distinct, under a magnifier, especially on the brachial valve.

Compared with other species at the same horizon, the shell of *Strophomena neglecta* is large and thin. Specimens 50 mm. in width, 40 mm. in length, and 15 mm. in convexity occur, but specimens 45 mm. in width, 35 mm. in length, and 12 mm. in convexity are more common. The flattened area anterior to the beak of the brachial valve extends for a distance of about 15 mm. from the hinge-area. The larger shells appear rather strongly and evenly convex when viewed from the side, the maximum curvature being about 20 mm. from the beak.

Compared with *Strophomena vetusta*, the hinge-area of the pedicel valve of *Strophomena neglecta* is more narrow; the brachial valve is more convex, and hence more deflected anterior to the postero-lateral angles; the flattened area of the brachial valve extends farther from the beak; the convexity anterior to the beak of the pedicel valve is more prominent and extends farther from the beak; the radiating striae of the brachial valve are finer; the vascular ridges and sinuses of the median parts of the brachial

valve usually are obsolete; the shell attains a larger size and is thinner, the interior of the pedicel valve not being conspicuously thickened toward the margin; and the muscular area of the pedicel valve is radiately striate or flabellate. The anterior terminations of the lateral borders of the muscular area are not deflected strongly to the front, on each side of the median anterior gap, as in the case of *Strophomena vetusta*.

Strophomena neglecta makes its appearance in the lower part of the Blanchester division of the Waynesville bed, either at the same time as *Strophomena nutans*, or a short distance above. The greatest vertical range is about 8 feet. At Owingsville, in Bath county, Kentucky, it occurs, associated with *Strophomena vetusta-precursor*, in a thin layer 12 feet below the *Dinorthis subquadrata* horizon. At Wyoming, in the southern part of Fleming county, it occurs 9 feet below the *Hebertella insculpta* horizon, which forms the base of the Liberty member. At Concord, in Lewis county, Kentucky, *Strophomena neglecta* occurs 15 feet below the *Hebertella insculpta* layer forming the base of the Liberty, and *Strophomena vetusta-precursor* comes in 4 feet above *Strophomena neglecta*.

The most southern exposure of the lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville member, is located almost directly south of the mouth of Gordon Run, along a road leading southward from Eagle Creek, about 5 miles west of West Union, in Adams county. Here *Catazyga headi* is abundant immediately above the lower *Hebertella insculpta* horizon. From this locality northwestward, *Strophomena neglecta* may be traced within the Blanchester division as far as the Narrows, east of the Pinnacles, and 4 miles southwest of Dayton, and then westward to the vicinity of Oxford, in the northwestern corner of Butler county. From the northern edge of Union county, in Indiana, to the vicinity of Brookville, in Franklin county, *Strophomena neglecta* occurs above the upper *Dinorthis carleyi* horizon, in strata also regarded as unquestionably belonging to the Blanchester division, since the upper *Dinorthis carleyi* horizon, in Ohio, belongs to the lower *Hebertella insculpta* zone, or immediately above. *Strophomena neglecta* is very common at Moores Hill, in Dearborn county. The most southern specimens occur north of Canaan, in the northern part of Jefferson county, 16 and 19 feet below the upper *Hebertella insculpta* horizon, which is located at the base of the Liberty member.

In the *Paleontology of Minnesota*, vol. iii, part 1, on page 388, Winchell and Schuchert refer to *Strophomena neglecta* a specimen from Savannah, Illinois. This specimen, from the Schuchert collection, is represented by Fig. 5 on plate VII of this Bulletin. The specimen is not distinct in any essential particular from an undoubted specimen of *Strophomena neglecta*, from Oregonia, Ohio, belonging to the Nickles collection. The latter (*Plate V, Fig. 3 B*) was figured because it was a narrow individual, presenting a somewhat triangular appearance, but the same features on the interior are presented by numerous other valves from the same locality, having the ordinary outline. A specimen similar to that from Savannah was found at the top of the hill immediately south of Kagawong, on Manitoulin Island (*Plate XI, Fig. 10*), in strata belonging a short distance above the *Hebertella insculpta* horizon, in the Richmond group. It is remarkable merely for being the only specimen of *Strophomena neglecta* discovered in a large series of *Strophomenas* found at essentially the same horizon at different localities on the island.

It is the presence of specimens of this type among the Richmond fossils of the Mississippi Valley which makes it desirable that *Strophomena planodorsata* be subjected to further study, on the basis of a much larger series of specimens than that at the service of the writer.

Strophomena neglecta is another of the species suggesting a connection between the Blanchester division of the Waynesville as exposed in Bath, Fleming and Lewis counties, in southwestern Ohio, and in Indiana as far south as Jefferson county, with the Richmond deposits in the Mississippi Valley by way of northern Illinois. By this is not meant an exact equivalency of the strata containing *Strophomena neglecta* to those containing *Strophomena planodorsata*, but at least an approximate equivalency.

Strophomena neglecta represents a reintroduction of the form of shell typified by *Strophomena incurvata*.

Strophomena vetusta-precursor, var. nov.

(*Plate X, Figs. 1 A, B, C; Plate V, Figs. 2 A, B, not the types*)

Typical specimens of *Strophomena vetusta* are abundant in the Whitewater bed. They are comparatively common in the Liberty bed, especially in the upper half. However, near the middle

of the Blanchester division of the Waynesville bed, the evident precursors of this species are not uncommon locally. Here they are associated with *Strophomena neglecta*. From the latter species they may be distinguished readily by the deflection of the lateral borders of the muscular area toward the front, leaving a median gap; by the tendency toward perpendicular wrinkling at the hinge-line; and by the irregular concentric wrinkling of the pedicel valve, accompanied by a corresponding deviation of the radiating striae from their usual straight-line directions.

Compared with the typical forms of *Strophomena vetusta*, from the Whitewater bed, the variety *precursor* usually has less prominent radiating striae on the brachial valve, even in cases where the number of striae is approximately the same. Frequently, however, the number of these striae equals 10 to 13, in place of 8 to 10, in a width of 5 mm. The area of the pedicel valve usually is not so conspicuously elevated, and the perpendicular wrinkling along the hinge-line usually is less in evidence. The four parallel ridges and intermediate vascular sinuses along the median parts of the interior of the brachial valve are less conspicuous. The interior of the valves is more minutely pustulose. In other words, the variety *precursor* differs but slightly from the typical Whitewater forms of *Strophomena vetusta*. The valves are thinner and less robust. Their chief interest lies in their earlier occurrence.

The types of the variety *precursor* were found in the Blanchester division of the Waynesville bed, along Penquite Run, two and a half miles west of Clarksville, Ohio, south of the pike, above the lower *Hebertella insculpta* horizon.

Strophomena vetusta-precursor occurs usually above the middle of the Blanchester division of the Waynesville member. It frequently is associated with *Strophomena neglecta*, especially in the lower part of its range, but at Moores Hill, in Dearborn county, Indiana; a mile and a half southwest of Oxford, in the northwestern part of Butler county, Ohio; at Oregonia, in Warren county; at Clarksville, in Clinton county; and at Concord, in Lewis county, Kentucky, its vertical range extends above that of *Strophomena neglecta*. At Moores Hill, its vertical range equals 11 feet, but usually it does not exceed 2 or 3 feet.

Its most southern range extends to Owingsville, in Bath county, Kentucky. Specimens are found also at Concord, in Lewis county; and on Eagle Creek, four miles west of West Union, in

Adams county, Ohio. It becomes more abundant northward, occurring in Stony Hollow, northwest of Clarksville, in Clinton county; also on Penquite Run, $2\frac{1}{2}$ miles southwest of Clarksville, in the eastern part of Warren county, and at Oregonia, in the same county. In Greene county, it occurs a mile northwest of Mount Holly, and a mile southeast of Bellbrook. In Montgomery county, it occurs at the Narrows, east of the Pinnacles, 4 miles southeast of Dayton; at Miamisburg; and a mile and a half southwest of Farmersville, where the road follows Twin Creek, in the northern edge of German Township. In Preble county, *Strophomena vetusta-precursor* occurs about a mile and a half northeast of Gratis, on Twin Creek; in Butler county, a mile and a half southwest of Oxford; in Dearborn county, Indiana, it occurs east of Weisburg, and much more abundantly, east of Moores Hill.

It is very probable that it is fairly common within most of the area here indicated, but the species has not been differentiated readily from *Strophomena neglecta* until recently, and is not often mentioned in the field notes.

Strophomena vetusta makes its first appearance in the Blanchester division of the Waynesville under the form of its variety *precursor*. Here it is distributed from Lewis county in Kentucky westward across southwestern Ohio to Dearborn county in Indiana. During the Liberty and Whitewater, its range was much more extended, reaching Nelson and Madison counties, in Kentucky. It is not known from any part of the Mississippi Valley Richmond or from the borders of Lake Huron or the vicinity of Toronto. As in the case of *Strophomena concordensis* and its related species, and also in the case of *Strophomena planumbona*, as far as its range in Ohio, Indiana, and Kentucky is concerned, *Strophomena vetusta* appears first in lower strata northward and then spreads later over a greater area southward. Since the same feature is shown also by *Strophomena sulcata*, the evidence seems to favor a northern basin, probably occupying a considerable part of Ohio and Indiana, probably more or less frequently cut off from the Mississippi Valley basin, within which a more or less characteristic Richmond fauna was developed and from which the fauna migrated at various times to varying distances southward. At times the connection with the Mississippi Valley basin may have been fairly good; for instance, at the beginning

and close of the Blanchester division, during the ingression of *Hebertella insculpta;* also early in the Liberty, during the ingression of *Dinorthis subquadrata;* probably also during the middle of the Blanchester, during the ingression of *Strophomena neglecta,* and later, during the ingression of *Austinella scofieldi.* During the greater part of the Liberty, however, and during all of the Whitewater, this basin in Ohio and Indiana appears to have been entirely cut off from the Mississippi Valley Richmond seas.

Strophomena vetusta, James[13]

(Plate VI, Figs. 2 A, B, C, D, E, F, G, H)

The muscular area of the pedicel valve equals in width about one-third to two-fifths of the width of the shell. Postero-laterally, the muscular area is abruptly limited by a sharply ascending border. Antero-laterally, the surface of the area rises more gradually toward the border, and here the limiting border may rise sharply above the general surface of the interior of the valve, or only the outer slope of the border may be sharply defined. The surface of the muscular area is not conspicuously striated in a radiate or flabellate manner, as in *Strophomena neglecta.* Anteriorly, the lateral border is deflected forward, leaving a rather broad median gap, which is one of the characteristics of this species. A rather narrow median ridge, widening only slightly posteriorly, indicates the line of attachment of the adductor muscles. The deflected anterior terminations of the lateral borders of the muscular area are extended anteriorly as ridges, between which one or two additional ridges may appear, the various ridges being separated by the vascular sinuses. These ridges and intermediate grooves are much less distinct than those on the median parts of the brachial valve, and usually extend only about half way from the muscular area toward the anterior margin of the valve. The shell usually is only moderately thickened along the anterior and lateral edges.

The interior of the brachial valve is marked by four strong parallel ridges with the intermediate vascular sinuses. Posteriorly, they terminate within the diductor area, the two inner ridges having a tendency to unite with the median elevation

[13] *Cincinnati Quarterly Journal of Science,* vol. i, p. 241, 1874.

extending forward from the thickened portion of the shell beneath the cardinal process. The interior of the brachial valve is marked by irregular, elongated papillae or short ridges, which become coarser toward the vascular markings and toward the posterior parts of the shell, but are finer toward the lateral and anterior margins. Their arrangement usually is very irregular. Similar markings are found on the interior of the pedicel valve. They give a roughened or shagreen effect to the surface of the interior.

The most characteristic features of the exterior of the shell are the high hinge-area; the usually conspicuous wrinkling of the posterior part of the shell, approximately perpendicular to the hinge-line; the very fine radiating striae on the pedicel valve, and the much coarser striae on the brachial valve. In a shell 33 mm. wide, the height of the hinge-area of the pedicel valve may equal 4 or 5 mm. at the beak. In some of the thicker specimens, the height of this hinge-area may be fully 1.7 mm. within 2 mm. of the lateral terminations of the area. The wrinkling of the posterior part of the valves, perpendicular to the hinge-area, extends only a short distance from the area near the beaks, the extent of the wrinkling increasing toward the postero-lateral angles of the valves, sometimes involving the shell to a distance of 5 or 6 mm. from the hinge-area. The number of radiating striae on the pedicel valve frequently equals 18 to 21 in a width of 5 mm., 25 mm. from the beak, but may be as low as 14 in the same width. Occasionally, every fourth one of these striae is slightly more prominent. Usually the radiating striae are crossed by a set of irregular concentric wrinkles and fine striae, accompanied occasionally by somewhat squamose lines of growth, rather irregular at the edges; moreover, the radiating striae tend to change more or less in direction, especially toward the anterior and lateral margins of the valves. The result is a peculiar irregular appearance of the markings on the exterior of the pedicel valve which is very diagnostic of this species. The number of radiating striae on the brachial valve equals 8 to 10 in a width of 5 mm. at 25 mm. from the beak. Toward the beak, every second or fourth striation may be more prominent, but anteriorly the striae are more nearly of the same size, or alternate in part, the intermediate striae being comparatively inconspicuous. The two valves differ greatly in the coarseness of their striations.

The shells may attain a width of 40 mm. The length of the

larger specimens may vary from 26 to 30 mm. The postero-lateral outlines are either rectangular or slightly extended along the hinge-line. The brachial valve is almost evenly convex, the flattening at the beak being inconspicuous. In a corresponding manner, the concavity of the pedicel valve is comparatively uninterrupted at the beak, the convexity immediately anterior to the beak usually being inconspicuous. The convexity of the brachial valve equals 8 mm. in shells 33 mm. in width.

In the original description, the type specimens are stated to have come from the upper part of the Cincinnati group, in Ohio and Indiana. In the James collection, preserved in the Walker Museum, at Chicago University, a series of specimens, numbered 1567, is labelled as forming the types of *Strophomena vetusta*, and as coming from Blanchester, Ohio. An examination of these specimens suggests that they are characteristic Liberty or Whitewater forms, and not the form from the Blanchester division of the Waynesville bed, here called *Strophomena vetusta-precursor*. Of these types, four are illustrated by Figs. 2 *B*, *C*, *D*, and *E*, on plate VI of this Bulletin.

The first appearance of *Strophomena vetusta* is in the Blanchester division of the Waynesville, where it bears the name *Strophomena vetusta-precursor*, and where the valves are distinctly thinner than in the more typical specimens, found in the Liberty and Whitewater beds. At those localities at which *Strophomena planumbona*, or *Strophomena planumbona-subtenta*, is very abundant in the lower part of the Liberty, *Strophomena vetusta* comes in near the middle of the Liberty and does not become abundant until the upper part of the Liberty is reached. This appears to be true at Concord, Kentucky, and near Clarksville, Camden, and elsewhere in Ohio. In the Whitewater bed, however, it ranges from the base to the top.

On the eastern side of the Cincinnati geanticline, *Strophomena vetusta* has been identified with certainty as far southward as Wyoming, in the southern part of Fleming county, and with considerable probability as far as College Hill, in the northeastern part of Madison county. From Wyoming southward, its vertical range appears to be in the Liberty. Northward, in Ohio and Indiana, it occurs also in the Whitewater bed.

On the western side of the Cincinnati geanticline, in Kentucky, *Strophomena vetusta* can be traced as far southward as Bardstown,

and a locality 4 miles east of Bardstown, in Nelson county, in the Liberty member. If the fossiliferous strata overlying the Saluda are to be regarded as Whitewater, then *Strophomena vetusta* occurs in the Whitewater as far south as the northwestern corner of Ripley county, and the southern part of Decatur county. Farther northward, in Indiana and Ohio, it is abundant at the Whitewater horizon.

Strophomena vetusta is found occasionally in the lower part of the Saluda member, above the *Columnaria* horizon, in Jefferson and Ripley counties, in Indiana.

Strophomena vetusta-approximata, James[14]

(*Plate VI, Figs. 1 A, B, C, D*)

Strophomena approximata was described by U. P. James from the upper part of the Cincinnati group, in Dearborn county, Indiana. Two specimens, numbered 2394, and labelled *Strophomena approximata,* occur in the James collection, preserved in the Walker Museum, at Chicago University. These are illustrated in this Bulletin. The larger specimen was used for the original description by James. An examination of the types indicates that they are very closely related to *Strophomena vetusta,* and differ only in outline. The specimens are subtriangular, rather than subquadratic in outline. Specimens of this type are very rare, and occur only as isolated individuals at distant localities, and only where *Strophomena vetusta* is abundant. Apparently these triangular specimens are to be regarded merely as pathological variations from *Strophomena vetusta,* and not as varieties tending toward the formation of a new species. The types have the appearance of specimens from the Whitewater bed, but there is also a possibility of their having been obtained in the Liberty bed, and the latter is exposed at Moores Hill, at Weisburg, and at other localities in the northwestern part of Dearborn county, in Indiana. The brachial valve of the type of *Strophomena vetusta-approximata* is flattened for some distance anterior to the beak. The length of the shell is 3.2 mm., and the greatest convexity equals 10.3 mm. at 18.5 mm. from the beak. The thickness of the shell at this point is 4.1 mm. The width of the shell

[14] *Paleontologist,* No. 5, p. 43, June 10, 1881.

along the hinge-line is 4.5 mm. The height of the hinge-area is 5.3 mm. The radiating striae of the brachial valve are rather coarse, one or two finer striae occurring between some of the coarser ones. At 25 mm. anterior to the beak, about 10 of the coarser striae occur in a width of 5 mm. Radiating striae of the pedicel valve distinctly finer and more numerous, about 15 in a width of 5 mm., at a point 25 mm. from the beak, not counting the finer intercalated striae. Posterior half of the pedicel valve concentrically wrinkled. Hinge-area broadly triangular, 5.3 mm. in height at the beak.

Strophomena sulcata, Verneuil[15]

(Plate I, Figs. 4 A, B, C; Plate XI, Figs. 2 A, B)

Strophomena sulcata was described by de Verneuil in the *Bulletin Société Géologique de France,* vol. V, page 350, in 1848. Figs. 4 *a*, and 4 *b*, on plate IV, accompanying the original description, suggest the presence of rather coarser radiating striae than those typical of the Richmond species usually identified as *Strophomena sulcata*; the height of the hinge-area of the pedicel valve, as figured, is too great, the anterior outline of the shell appears too incurved for a specimen exhibiting the hinge-area well, and the lateral outlines of the shell are not those most common, although occasionally found. De Verneuil's collection at present is located at the École des Mines, at Paris. Neither *Strophomena sulcata* nor *Protarea verneuili* can be found there. The types apparently have been lost. However, the reference to the conspicuous sinus of the valve at present called the pedicel valve, and the statement that *Strophomena sulcata* is found in the blue limestone of Ohio and Indiana, are sufficient to indicate that the Richmond species was being described. *Strophomena sinuata* is so very rare in Indiana, that it is extremely unlikely that this species was obtained by de Verneuil from that state. *Strophomena sulcata,* as identified from the Richmond, however, is common at several horizons in both states, and always attracts the attention of collectors.

Shells small; width usually varying between 18 and 23 mm., rarely equalling 30 mm. Ratio of length to width usually between 0.67 and 0.75, but it may be as low as 0.61 and as high as 0.80.

[15] *Bulletin, Société Géologique de France,* vol. v, p. 350, 1848.

Hinge-line usually approximately equal to or only slighter longer or shorter than the width of the shell across the middle, the lateral margin meeting the hinge-line nearly at right angles. Occasionally, the length of the hinge-line exceeds the middle width of the shell conspicuously, and the lateral margins of the shell may meet the hinge-line at angles as low as 63 degrees.

Brachial valve flat at the umbo, usually raised anteriorly along the median line so as to form a more or less prominent median elevation. Shell usually nearly straight or only slightly convex from front to rear along this median elevation, especially when the latter is prominent.

Pedicel valve moderately convex near the beak, more or less depressed anteriorly, forming a shallow median sinus along the anterior half of the valve.

Radiating striae within a distance of 1 cm. from the beak usually between 50 and 55, but occasionally as few as 45 or as many as 70 in number. When the striae are numerous the primary striae are not conspicuously larger than the secondary. However, when the striae are less numerous, the former often are so much more conspicuous that the shell appears rather coarsely striated. In extreme cases the shells are striated almost as coarsely as in typical specimens of *Strophomena sinuata*. If de Verneuil's statement, that *Strophomena sulcata* occurs along with *Strophomena planoconvexa*, were taken literally, then the coarseness of the striations in his figures would be readily accounted for, since the radiating striations of *Strophomena sinuata* are typically coarser.

Average specimens of *Strophomena sulcata* may be readily distinguished from *Strophomena sinuata* by the stronger median elevation and depression, by the straightness or moderate convexity of the brachial valve from front to rear along the median line, and by the less coarse or decidedly finer radiating striae.

In shells having the more numerous and finer radiating plications, the median elevation and depression often are but slight; in some cases even less than in typical specimens of *Strophomena sinuata*. When these features are accompanied by a conspicuous elongation of the shell along the hinge-line, so that the lateral margins form acute angles with the latter, the shells differ conspicuously from the more typical quadrate forms of *Strophomena sulcata*. However, the transversely elongate forms occur only

in association with those having quadrate outlines, and both are connected by so many intermediate forms, that they are not distinguished here even as varieties.

The muscular area of the pedicel valve equals about three-tenths of the width of this valve. Postero-laterally it is distinctly bounded by a sharp border extending forward from the teeth; laterally, this border rapidly diminishes in height; and along the anterior margin of the area there usually is no trace of the border. A rather faint median line of elevation, widening posteriorly, traverses this area and indicates the line of attachment of the adductor muscles. In the interior of the brachial valve, the two lobes of the cardinal process, the divergent crural plates, and the median ridge extending forward from the callosity immediately in front of the cardinal process, are well developed, considering the size of the shell. The median ridge, mentioned above, terminates at the anterior end of the adductor areas. Sometimes the adductor areas are clearly defined anteriorly, but frequently there is only a rather vague suggestion of this outline. The vascular ridges and sinuses found along the median parts of the brachial valve in other species of *Strophomena*, usually are imperfectly indicated or absent. The location of the radiating striae ornamenting the exterior of the shell frequently can be detected on the interior. Aside from the markings already described, the general surface of the interior is smooth, or is covered by minute papillae seen only under a magnifier.

In Stony Hollow, northwest of Clarksville, in Clinton county, Ohio, *Strophomena sulcata* is seen at the very base of the Clarksville division of the Waynesville member, immediately above the *Orthoceras fosteri* clay bed. From this horizon, it ranges upward a distance of 7 feet, and is fairly common in several layers. Most of the specimens are distinctly sinuate anteriorly, as the name suggests, and the radiating plications of most specimens are rather coarse, a fact which is true also of the specimens found at the lower *Hebertella insculpta* horizon. Occasionally, however, specimens are found in which these plications are about as numerous as in the Liberty and Whitewater forms.

About 1 foot above the base of the Clarksville division, in Stony Hollow, northwest of Clarksville, brachial valves of *Strophomena sulcata* occur, which are almost evenly convex. Some of these specimens are 24 mm. wide. In that case they bear some resem-

blance to the brachial valves of *Strophomena planoconvexa*. The pedicel valves of these specimens are unknown, and there is no reason as yet for regarding them as anything more than aberrant individuals of *Strophomena sulcata* in which the sinuate flexure of the anterior half of the shell failed to develop.

A mile and a half southwest of the railroad station at Fort Ancient, in Warren county, Ohio, *Strophomena sulcata* ranges from 1 to 4 feet above the *Orthoceras fosteri* clay layer.

East of Moores Hill, in the western part of Dearborn county, Indiana, *Strophomena sulcata* also occurs in the lower part of the Clarksville division, over strata containing *Strophomena planumbona*. Both *Strophomena sulcata* and *Strophomena planumbona* have an extended vertical range in the Richmond, and both are seen first in the lower part of the Clarksville division, but *Strophomena sulcata* appears to have arrived a little later.

Strophomena sulcata recurs at the lower *Hebertella insculpta* horizon, at the base of the upper or Blanchester division of the Waynesville bed. It occurs at this horizon at Stony Hollow, northwest of Clarksville, also along Sewell Run, southeast of Clarksville, and along Second Creek, northeast of Blanchester, in Clinton county, Ohio. It occurs at the same horizon along the creek $1\frac{1}{2}$ miles southeast of Fort Ancient, in Warren county; half a mile south of Mount Holly, in the northern part of Green county; at Miamisburg, in Montgomery county; and along Dry Fork of Elk Run, $1\frac{1}{4}$ miles south of Jacksonburg, in the northern part of Butler county, Ohio. At Concord, in Lewis county, Kentucky, it occurs 18 feet below the upper *Hebertella insculpta* horizon, or 3 feet below the *Strophomena neglecta* layer. This should place it near the base of the Blanchester division.

In the Liberty member, *Strophomena sulcata* occurs in Clinton county, Ohio, at various levels between the base and top. West of Camden, in Preble county, it occurs in the lower part of the Liberty, and it is found in the same position also at Concord, in Lewis county, Kentucky. Westward, it occurs apparently at least as far as Madison, in Jefferson county, Indiana.

In the Whitewater member, *Strophomena sulcata* occurs in Clinton county, Ohio, at various levels from the base to the top. While abundant also at other levels, it has been noted especially near the top of the Whitewater member, from Clinton county, Ohio, as far south as the locality west of Spencer in Montgomery

county, also the one west of Indian Fields, in Clark county, and the one east of College Hill, in Madison county, all in Kentucky. Northward, in Ohio, it occurs at the top of the Whitewater as far as Dayton, in Montgomery county, and thence, westward, at various localities in Preble and Butler counties, as far as Richmond, in Indiana.

If the fossiliferous strata overlying the Saluda bed in Ripley, Decatur, and Jennings counties, in Indiana, are to be regarded as of Whitewater age, then *Strophomena sulcata* may be traced at this horizon as far westward as Decatur county, and as far southward as the locality about $2\frac{1}{2}$ miles south of Versailles, in Ripley county.

If the fossiliferous strata immediately below the Saluda member, in western Kentucky, are to be regarded as Liberty, then *Strophomena sulcata* may be traced at this horizon as far south as the localities east of Jeffersontown and near Mount Washington, in Jefferson county; those in the eastern part of Bullitt county; east of Bardstown, in Nelson county; and east of Raywick, in the southwestern part of Marion county.

In the Saluda member, *Strophomena sulcata* occurs at Madison, Indiana, 7 feet above the great *Columnaria* horizon, which here forms the base. West of Weisburg, in the northwestern part of Dearborn county, it occurs near the middle of the section which here intervenes between the so-called shale layer near the base and the typical mottled limestone, which forms the top of the Saluda section.

Strophomena sulcata is not known, at present, from the Elkhorn member.

From these data it appears that *Strophomena sulcata* has a vertical range from the base of the middle or Clarksville division of the Waynesville member to the top of the Whitewater member of the Richmond.

The most southern locality known at present at which *Strophomena sulcata* occurs is north of Dismukes Station, in Sumner county, Tennessee. Here it is found associated with *Rhynchotrema dentata, Leptaena richmondensis, Strophomena planumbona,* and other fossils, at a horizon probably near the upper or Blanchester division of the Waynesville bed. The nearest exposure in Kentucky, containing *Strophomena sulcata,* is located in the northeastern corner of Raywick, in Marion county, 95 miles

distant. At the latter locality, this fossil occurs at the southern limit of extension of the *Dinorthis subquadrata* and *Strophomena vetusta* fauna, these fossils occurring at Bardstown and other localities in Nelson county, farther northward. The horizon is regarded as about equivalent to the Liberty member of the Richmond, and as above the horizon of the *Strophomena sulcata* fauna at Dismukes Station. The nearest known locality of *Strophomena sulcata* at the Blanchester horizon probably occurs in southern Indiana, near Madison.

In the Richmond on Manitoulin Island, *Strophomena sulcata* occurs at various levels between the *Hebertella insculpta* horizon and the rich coral bed, 40 or 50 feet farther up. It occurs at this horizon at Little Current, Kagawong, and Gore Bay. The strata are regarded as approximately equivalent to the Blanchester division of the Richmond.

Geographically, *Strophomena sulcata* makes its first appearance near the base of the middle or Clarksville division of the Waynesville, in Ohio and Indiana. It may have had an equally great distribution near the base of the upper or Blanchester division, but at present it is definitely known at this horizon only in a rather restricted area in southwestern Ohio. The fact that it occurs also at the Waynesville horizon near Gallatin, in northern Tennessee, is in favor of its migration from some region accessible to both areas. Judging from the discoveries on Manitoulin, this Waynesville sea extended to the northern edge of Lake Huron. In the Liberty sea, *Strophomena sulcata* ranged as far south as Concord, on the Ohio River in eastern Kentucky, and to Raywick, in Marion county, in western Kentucky. In the Whitewater sea, its range extended as far south as Madison county, in eastern Kentucky, and as far as Ripley county, in Indiana.

On the accompanying chart (plate XVIII), the range of *Strophomena sulcata* during the Waynesville is indicated by the areas crossed by diagonal lines. Its range during the Liberty and Whitewater is indicated by the much more extended area enclosed by the dotted line. Its range at the lower *Hebertella insculpta* horizon, at the base of the Blanchester, appears to have been more restricted than earlier, during the Clarksville period of deposition, although the species appears to be more constant in its occurrence at the base of the Blanchester than at the lower horizons.

Strophomena sulcata is most abundant in the Liberty and Whitewater, especially near the top of the Whitewater.

Owing to the absence of *Strophomena sulcata* from the Richmond of the Mississippi Valley, with the possible exception of a limited area in southern Illinois, it is another species, suggesting perhaps an indigenous origin in some basin including Ohio and Indiana.

Strophomena cardinalis, Whitfield[16]

The chief characteristics of *Strophomena cardinalis* it shares with *Strophomena wisconsinensis,* described from the same horizon and locality. These characteristics are the high hinge-area, nearly parallel with the flattened posterior part of the brachial valve, the relatively large convex area anterior to the beak, and the rather strong downward deflection of the brachial valve anterior to the flattened area. The reversal in the curvature of the pedicel valve from convex to concave is only slight, and takes place so near the anterior margin as to suggest that the types of this species were immature shells. Opposed to this view is the great height of the hinge-area in specimens of comparatively small size. In the figured specimen, the width of the shell is 22 mm.; the length 17 mm.; and the height of the hinge-area, nearly 4 mm. In general, the height of the hinge-area is nearly one-fifth of the length of the shell. In form, the area is conspicuously triangular. Richmond group, at Delafield, Wisconsin.

It is a suspicious circumstance that *Strophomena cardinalis* does not reappear in the collections made, since this species was described, at Delafield, and at other localities containing strata belonging to the same horizon.

Strophomena wisconsinensis, Whitfield[17]

(Plate VII, Figs. 1 A, B, C; Plate IX, Figs. 5 A, B, C)

The types were obtained from the Richmond beds at Delafield, Wisconsin. Their most characteristic feature is their great convexity. The brachial valve is highly arcuate and gibbous near the middle, the greatest convexity being at the middle

[16] *Geology of Wisconsin,* vol. iv, 1882, p. 261, Plate XII, Figs. 9, 10.
[17] *Geology of Wisconsin,* vol. iv, p. 263, 1880.

or even posterior to the middle of the valve. The posterior part of the valve is distinctly flattened, and the part immediately anterior to the beak is slightly concave. The pedicel valve is rather deeply concave, although distinctly convex near the beak.

These characteristics are possessed by the three specimens from the Richmond group at Wilmington, Illinois, figured in this Bulletin, all from the Schuchert collection. The hinge-area of the pedicel valve is rather high and is approximately parallel to the flattened surface of the brachial valve. This feature is best seen when the shell is viewed from the side. The muscular area of the pedicel valve is subcircular. The limiting lateral ridges rise prominently above the body cavity; they are not strongly deflected toward the front anteriorly. Vascular markings extend radially toward the anterior margin of the valve. They are distinct even 10 mm. back from this margin, and the shell is only moderately thickened within the area traversed by them. The radiating striae are about as fine as those of *Strophomena planumbona*, or slightly coarser.

Compared with *Strophomena concordensis*, the brachial valve is more gibbous, the hinge-area of the pedicel valve is higher, and it is more nearly parallel to the flattened posterior part of the brachial valve.

Strophomena planodorsata, Winchell and Schuchert[18]

(Plate VII, Figs. 4 A, B; 6; 7 A, B; 8; Plate IX, Figs. 6 A, B; 7; 8 A, B; 9; 11; 12; 14 A, B)

The figures of the type, from the Richmond group at Spring Valley, Minnesota, are reproduced as Figs. 6 *A*, *B*, on plate IX, of this Bulletin. The chief feature of this shell consists in its large size, subquadrate outline, and fine surface striation. The flatness of the brachial valve for more than half its length is very unusual in specimens of this large size and is well described by the term *planodorsata*. In a similar manner, the pedicel valve is only slightly concave for more than half its length, then curves up rapidly toward the anterior and lateral margins.

Compared with this shell, the flattened area on the posterior half of the brachial valve of *Strophomena neglecta* certainly is less

[18] *American Geologist*, vol. ix, p. 286, 1892.

extensive, and if this be a constant specific difference, it warrants the separation of *Strophomena planodorsata* from that species.

It is doubtful, however, whether the extensive flattening of the posterior part of the brachial valve in the type of *Strophomena planodorsata* will prove even a fairly constant specific feature. A number of large specimens, apparently identical with typical *Strophomena planodorsata*, occur in the T. E. Savage collection from the Fernvale limestone at Thebes, Illinois, but the specimens are all pedicel valves. These valves have about the same curvature as that indicated for the pedicel valve of the type in Fig. 6 A on plate IX. The valves vary in length from 35 to 40 mm., the reversal of the curvature begins at 20 mm., but becomes distinct at 25 mm. from the beak. The number of radiating striae varies from 7 to 8 in a width of 2 mm., where not increased by implantation of intermediate striae. It is probable, however, that the brachial valve has a much more pronounced curvature and is ornamented by distinctly coarser striae than those on the pedicel valve.

Various specimens, from the Richmond group at Wilmington, Illinois, have been identified by Schuchert with *Strophomena planodorsata*. Some of these present views of the interior of the pedicel valve. One specimen was used for Fig. 10, on plate XXXI, of the *Minnesota Geological Survey*, vol. III, part 1, and the same specimen, belonging to the Schuchert collection, is illustrated by Fig. 6 on plate VII of the present Bulletin. The height of the hinge-area in this specimen is 4.2 mm. The muscular area is nearly circular, and is characterized by flabellate markings separated by a single distinct median ridge. The interior of this area rises gradually toward the limiting ridge, which descends abruptly into the body cavity. Posteriorly it approaches the hinge-line exterior to the teeth. The curvature of this valve is indicated by Fig. 7 on plate IX.

Similar interiors of pedicel valves of equal size, from the Fernvale limestone at Wilmington, Illinois, collected by Prof. T. E. Savage, indicate that the narrow thickened border, along the anterior and lateral margin of the pedicel valve figured by Schuchert, is not a constant feature, and usually is absent. Instead, there is a moderate thickening of the interior, with its maximum between 5 and 7 mm. from the margin, fading away posteriorly. This thickened area is crossed by rather incon-

spicuous radiating vascular markings. The muscular area is large, compared with the size of the valves, but the posterolateral border of this area does not join the hinge area farther exterior to the teeth than in many a specimen of typical *Strophomena neglecta* from Ohio and Indiana. One brachial valve is flattened for 20 mm. posteriorly, and then is strongly deflected downward at about 80 degrees for a distance of 30 mm., the direct length of the shell being 40 mm. Evidently, strong curvatures are to be expected in some of the shells, anterior to the flattened posterior area, in *Strophomena planodorsata*. The radiating striae were subequal or alternated in size, about 7 or 8 occuring in a width of 2 mm. On a brachial valve from the same locality, belonging to the Schuchert collection, there are 15 subequal radiating striae in a width of 5 mm. near the anterior margin. Over the flattened area near the middle of the valve, some of the striae are more prominent, and are separated by 3 to 5 finer ones.

Two specimens of smaller size, from the Richmond beds of Wilmington, Illinois, also belonging to the Schuchert collection, are illustrated by Figs. 7 *A*, *B*, on plate VII, and Figs. 8 *A*, *B*, and Fig. 9 on plate IX of this Bulletin. On the flattened area of the brachial valve certain striae are slightly more prominent, and are separated from each other by 4 or 5 finer striae. Anterior to the flattened area, the striae become more nearly equal in size, about 19 or 20 occupying a width of 5 mm. along the anterior margin. The pedicel valve has a circular muscular area with flabellate markings. The margin of this area is scarcely raised above the general surface of the body cavity. At the hinge-line the area is better defined, but here the border does not meet the hinge-line distinctly exterior to the teeth. Possibly this border moves outward with increased maturity of the shell. The greatest convexity of the complete but somewhat crushed shell, 16 mm. from the hinge-line, is 10 mm. Height of the hinge-area of the pedicel valve, 4 mm. The shell is 26.5 mm. long, and the flattening of the brachial valve extends for a distance of about 15 mm. from the beak.

With these smaller forms of *Strophomena planodorsata* from Wilmington, Illinois, I have identified some specimens from the Richmond beds in western Tennessee. About 17 radiating, subequal striae occupy a width of 5 mm. Specimens with the flat-

tening of the brachial valve extending for more than half the length of the shell from the beak were noticed at Clifton, and near the home of W. D. Helton, on Beech Creek, 3 miles northwest of Waynesboro. Others, with the flattening extending only as far as the middle, were seen at Riverside, and along Leipers Creek in Maury county, north of Fly's store. A specimen from the last locality is illustrated by Figs. 4 *A*, *B*, on plate VII and Figs. 14 *A*, *B*, on plate IX of this Bulletin.

A pedicel valve from Iron Ridge, Wisconsin, forming No. 8191 of the University of Minnesota collection, is illustrated by Fig. 8 (magnified) on plate VII of this Bulletin. The muscular area resembles that of Fig. 7 *A* on the same plate. The interior of the body cavity is marked by minute granules arranged in radiate lines, about 35 in a width of 5 mm. These granules are characteristic of the species. The valve is very flat, and is very moderately curved at the anterior end.

Excepting in the outline of the shell, the last specimen closely resembles the specimen of *Strophomena neglecta* from Oregonia, Ohio, illustrated by Fig. 3 *A*, on plate V. The latter specimen presents the same flabellate scar, scarcely rising above the body cavity at the border, and also the numerous minute granules arranged more or less in radiating series. Other specimens of *Strophomena neglecta* occur which resemble the larger valve of *Strophomena planodorsata* illustrated by Schuchert from Wilmington, Illinois (illustrated also by Fig. 6, on plate VII, of this Bulletin). In fact, the interiors of *Strophomena neglecta* vary considerably, but all agree in having flabellate muscular areas, and numerous small granules more or less arranged in radiating lines, but the size of these granules varies considerably.

The prominence of the border surrounding the muscular area of the pedicel valve is not of diagnostic value. This feature varies considerably in different individuals of the same species. Typical specimens of *Strophomena planodorsata* from the Fernvale at Wilmington, Illinois, often have prominent borders, while in a suite of specimens from Sterling, Illinois, regarded as *Strophomena neglecta*, this border varies from fairly prominent to as low as in the specimen here figured from Iron Ridge. In these specimens from Sterling, the shell usually is about 27 mm. long, 40 mm. wide at the hinge-line, and only 35 mm. wide about 9 mm. in front of hinge-area. There are 11 or 12 sub-

equal striae in a width of 5 mm., or 7 or 8 stronger striae with enough intermediate narrower ones to give a total of 15 striae in this width. On the pedicel valve, the number of striae equals 17 subequal in a width of 5 mm., or 15 stronger ones with sufficient finer ones to give a total 19 or 20 in the same width.

There is no doubt that *Strophomena planodorsata* represents the western variant of *Strophomena neglecta*. Whether the species are to be regarded as essentially distinct must be determined from a much larger series of specimens than those which I have had the privilege of examining. Considering the distance between the area within which *Strophomena planodorsata* has been identified, and that in Indiana, Ohio, and adjacent Kentucky, within which *Strophomena neglecta* abounds, there is a probability of their being at least geographical variants, belonging to partially separated epicontinental oceanic basins.

Strophomena fluctuosa-occidentalis, nom. nov.[19]

(*Plate IX, Figs. 17 A, B, C, D; Plate X, Figs. 9 A, B, C, D, E*)

The species described by Winchell and Schuchert from Spring Valley, Minnesota, is a much smaller form than that figured by Billings under *Strophomena fluctuosa*, nor has it the greatly extended hinge-line. The wrinkles are concentric and are confined to the posterior flattened area of the valves; they are more or less conspicuously interrupted where they are crossed by the more prominent radiating striae. The latter alternate, at the geniculate deflection, with 7 to 11 much finer and quite inconspicuous striae. At the beginning of this deflection, the median one of the finer striae becomes conspicuous, and, farther down the slope of the deflection, the median striae of the secondary groups of finer striae become conspicuous in turn, especially along the median parts of the shell, so that along the border of the nasute part of the shell, and sometimes also laterally, there is an alternation of stronger striae with only one, two, or three finer ones.

The most characteristic feature of the brachial valve is the relatively great height of its hinge-area, considering the small size of the shell. This height equals about 1 mm. in shells having a width of 20 mm. The posterior part usually is conspicuously

[19] *Minnesota Paleontology*, vol. iii, part 1, Plate XXXI, Figs. 14–17, 1893.

flattened, with a moderate concavity toward the beak. The strong downward deflection anteriorly and laterally takes place from 10 to 11 mm. from the beak; and the anterior slope of the valve frequently reaches a length of 13 to 20 mm. In that case the shell has a triangular, or subpentagonal, nasute outline. The upper faces of the lobes of the cardinal process are flat, resting upon a callosity which extends laterally to the inner sides of the sharp crural plates, and anteriorly merges into the conspicuous median ridge separating the rather deeply impressed adductor scars. No conspicuous vascular ridges and sinuses were noticed anteriorly along the median parts of the shell, but distinctly defined grooves throughout the interior of this valve indicate the location, exteriorly, of the more prominent radiating striae.

Deltidium of the pedicel valve less conspicuous than usual on account of the strongly developed chilidium of the brachial valve. The hinge-area is fairly high, the hinge-teeth are relatively coarse and strongly supported by the callosity filling in the space between the hinge-area and the general interior of the valve. In fact, both valves are thick, and represent gerontic conditions. The muscular area is subcircular, with the postero-lateral diductors narrow, bordering the support of the hinge-teeth. The area is crossed by a median ridge, as usual. The interior of the shell is thickened anteriorly, especially along the median parts, and there is a tendency toward a "knotted" elevation of this part of the thickened border as in *Strophomena nutans*. The border is crossed by vascular grooves.

The shell usually does not exceed 23 to 25 mm. in width.

As far as the subpentagonal, nasute outline, and the strong median thickening of the interior of the pedicel valve are concerned, it is believed that these features do not suggest relationship to *Strophomena nutans*, but that they indicate similar gerontic stages of two quite dissimilar species produced by a retarded growth of the shell, accompanied by an increased thickening of the valves, and a more sudden deflection of the anterior and lateral margins. Any marked increase in the amount of shell material added to the interior of the valves is likely to be accompanied by a greater curvature of the valves, to provide the necessary room for the living parts, and if the lateral growth is greatly retarded, the additional room is provided anteriorly, resulting sometimes in a subnasute outline.

In a similar manner, I was not able to convince myself that the specimen from the Clay Cliffs, 3 miles north of Wekwemikongsing, on Manitoulin Island, resembling *Strophomena nutans*, (plate XI, Fig. 8) was not a variation of *Strophomena huronensis*, without any direct connection with the Ohio and Indiana specimens of *Strophomena nutans*.

Strophomena acuta, Winchell and Schuchert [20]

(Plate VII, Figs. 3 A, B, C, D; Plate IX, Figs. 13 A, B)

Strophomena acuta was described as a variety of *Strophomena neglecta*, but it is evident from the exterior that it bears no resemblance to that species, nor is it related to *Strophomena incurvata*. *Strophomena incurvata* and *Strophomena neglecta* belong to the group of *Strophomena* characterized by fine radiating surface striae, and by a rounded, flabellate muscular area in the pedicel valve. These features are not possessed by *Strophomena acuta*.

Among the specimens figured in this Bulletin, none are the actual figured types, although they came from the type locality, in the Richmond group, at Spring Valley, Minnesota. The specimens represented by Figs. 3 *A* and *B* on plate VII, belong to the Schuchert collection; those represented by Figs. 3 *C* and *D*, are included in the set numbered 5550 in the collection belonging to the University of Minnesota, and all of them may be regarded as cotypes.

General outline of the shell subtrigonal, the lateral outlines being moderately curved and converging from the cardinal angles toward the rounded anterior margins. Angle between the hinge-line and the general lateral contour of the shell 65 to 70 degrees; less commonly, 82 to 85 degrees. Valves usually wrinkled obliquely along the hinge-line.

Brachial valve flattened for a distance of 8 to 10 mm. from the beak, thence evenly convex toward the anterior margin; slightly, almost imperceptibly concave anterior to the beak for about 2 to 2.5 mm.

Pedicel valve slightly convex near the beak. Greatest concavity about 12 to 13 mm. from the beak.

Of the more prominent striae on the brachial valve about 6 or

[20] *Minnesota Geol. Survey*, vol. iii, p. 388, 1893.

7 occupy a width of 5 mm., separated by 3 or 4, sometimes 5, much less conspicuous striae. The striae of the pedicel valve are equal in number to those of the brachial valve, but the more prominent striae are relatively less conspicuous.

One of the specimens belonging to the Schuchert collection has the following dimensions. Width along the hinge-line, 29.5 mm.; across the center of the shell, 24 mm. Length of the pedicel valve, 21.7 mm.; of the brachial valve, 21 mm. Greatest convexity of the shell equals 8 mm. at 13.5 mm. from the beak; at this point the thickness of the shell is 5 mm. Length of the hinge-area, 29.5 mm.; height, 4 mm. In a more semicircular and more convex specimen from the same locality, belonging to set No. 3550 in the Chicago University collection, the greatest height of the shell is 10 mm. at 11.5 mm. from the beak; the length of the shell is 23 mm.

Leptaena gibbosa, James[21]

(Plate I, Figs. 5 A, B, C)

The types of *Leptaena gibbosa*, numbered 1114, are preserved in the James collection, in Walker Musum, at Chicago University. Three of the types are illustrated very inadequately in the present Bulletin. The radiating striae are so fine that they are not indicated with the grating used in the preparation of the accompanying plate. Usually one of the median radiating striations is stronger, sometimes two, and in one specimen, four of these median striations are stronger than any of the remainder. The other striae are very narrow and inconspicuous, about 20 to 26 occurring in a width of 5 mm. The types were found 80 feet above low-water mark in the Ohio River, at Cincinnati, Ohio, in the Economy member of the Eden. Similar specimens were found 11 feet above the base of the Eden at Boyd, on the Kentucky Central division of the Louisville and Nashville Railroad, and north of Ford, Kentucky, about a quarter of a mile before reaching the second railroad tunnel. In *Leptaena invenusta*, from the Gratz shale, 2 miles west of Drennan Springs, Kentucky, the number of radiating striae is about 15 in a width of 5 mm. (*Bull. Denison Univ.*, vol. XIV, plate VII, Fig. 3.)

[21] *Cincinnati Quarterly Journal of Science*, vol. i, p. 333, 1874.

In *Leptaena unicosta*, from the Richmond of Illinois and the states farther northwest, the median striation is much more conspicuous. Sometimes two of the median striae are more prominent. Concentric wrinkles are less conspicuous than in *Leptaena gibbosa*, and the absence of a strong concentrically curved elevation along that part of the pedicel valve where the geniculate deflection takes place, is a noteworthy characteristic.

Leptaena richmondensis, Foerste[22]

(*Plate I, Figs. 6 A, B, C*)

Leptaena richmondensis occurs in the Arnheim (plate I, Fig. 6 *A*) almost throughout the entire area of exposure in Ohio, Indiana, and Kentucky. On the western side of the Nashville dome, it extends southward as far as Clifton, on the Tennessee River. On the eastern side of the Cincinnati geanticline, from Stanford, in Lincoln county, Kentucky, northward into Ohio, and thence westward into Indiana, *Leptaena richmondensis* is confined to the lower part of the upper or Oregonia division of the Arnheim. It is assumed that this is the horizon of *Leptaena* also at the more southern exposures in Indiana, and thence southward as far as Marion and Casey counties, on the western side of the Cincinnati geanticline, in Kentucky. Northwestward, especially in Indiana, *Leptaena* is far less abundant than along the eastern line of outcrop in Ohio and Kentucky, and also southward along the western side of the Cincinnati geanticline, in west-central Kentucky.

Leptaena richmondensis is absent from the Arnheim in the western half of Lincoln county, and from the eastern parts of Boyle and Casey counties, in central Kentucky. It occurs in the northeastern part of Adair county, on Damron Creek, south of Green River, but is absent along the Cumberland River, in the southern part of the state.

In Tennessee, it occurs at the Arnheim horizon, north of Dismukes, 4 miles north of Gallatin. The occurrence at Clifton, on the Tennessee River, in the southern part of the state, has already been mentioned.

At most localities in Ohio, Indiana, and Kentucky, *Leptaena rich-*

[22] *Denison University Bulletin;* vol. xiv, p. 211, 1909.

mondensis makes its appearance in the Arnheim distinctly below the *Dinorthis carleyi* horizon, although locally the two fossils may be found associated. In Ohio, at Madison, in Indiana, and at the more northern localities in Kentucky on the western side of the Cincinnati geanticline, *Leptaena* occurs a short distance above a layer containing *Platystrophia ponderosa*. Farther southward, *Leptaena* and *Platystrophia ponderosa* are associated in the same layers. Still farther southward, *Platystrophia ponderosa* continues a considerable distance above the *Leptaena richmondensis* horizon, these conditions being prevalent throughout central Kentucky as far south as Lincoln, Casey, and Marion counties. For the Arnheim form of *Leptaena*, the term *Leptaena richmondensis-precursor* was proposed. (*Bull. Denison Univ.*, vol. XIV, p. 211. See also the *Ohio Naturalist*, vol. XII, plate XXII, Fig. 7.)

Leptaena richmondensis is not known in the lower or Fort Ancient division of the Waynesville member. In the middle or Clarksville division it makes its first appearance distinctly later than *Strophomena planumbona* and *Strophomena sulcata*. Near Blanchester and Clarksville, in Clinton county, Ohio, and near Fort Ancient, in Warren county, it makes its appearance quite constantly at $7\frac{1}{2}$ feet below the lower *Hebertella insculpta* horizon, and continues from this level at various intervals as far as the base of the Liberty member. It occurs in the upper part of the Clarksville bed also northeast of Somerville, in the southern part of Preble county, and southwest of McGonigle in Butler county.

Leptaena richmondensis is especially abundant at the lower *Hebertella insculpta* horizon, at the base of the upper or Blanchester division of the Waynesville. It occurs at this horizon in southwestern Ohio, from Oxford, in Butler county, to Blanchester, in the southwestern corner of Clinton county, wherever the lower *Hebertella insculpta* zone has been recognized. From this level it occurs at various intervals throughout the upper or Blanchester division. It is especially abundant in the Blanchester division in Ohio, and in the more northern counties in the Ordovician areas of Indiana, as far west as Weisburg, and Moores Hill, in the western part of Dearborn county. From these areas it extends southward in smaller numbers. At Concord, in Lewis county, Kentucky, *Leptaena richmondensis* occurs between 19 and 22 feet below the top of the Blanchester division. At Sunset, in the western part of Fleming county, it is found 12

feet below the top. At Wyoming, in the same county, it is seen 18 feet below the top. At Wyoming and Concord, the occurrences of *Leptaena richmondensis* are distinctly below the *Strophomena neglecta* horizon. It is probable that at these localities *Leptaena* indicates approximately the base of the Blanchester division of the Waynesville. At this horizon, *Leptaena* has not been found, so far, south of Fleming county, in east-central Kentucky.

On the western side of the Cincinnati geanticline, in Indiana, *Leptaena richmondensis* occurs in the upper or Blanchester division of the Waynesville, from the most northern exposures southward to Versailles, in Ripley county; north of Canaan, in the central part of Jefferson county; and at Madison (plate I, Figs. 6 *B*, *C*), in the same county. At the more southern localities in Indiana it is far less abundant than northward. At Milton, in Kentucky, opposite Madison in Indiana, *Leptaena* occurs between 19 and 30 feet below the lowest layers containing *Dinorthis retrorsa*, in strata probably belonging to the upper division of the Waynesville.

Two and a half miles northwest of Brownsboro, in Oldham county, Kentucky, *Leptaena richmondensis* occurs 8 feet below the lowest strata containing *Dinorthis subquadrata*, and also 17 feet lower, below a horizon at which *Calapoecia cribriformis* occurs loose. Three miles west of Brownsboro, in the same county, *Leptaena* is found 10 feet below the *Columnaria calycina* horizon, in strata regarded as belonging to the upper part of the Waynesville member.

Leptaena richmondensis is widespread in the lower part of the Liberty member, especially a short distance above the upper *Hebertella insculpta* horizon. At this horizon, it is found throughout the Ohio areas of exposure as far south as Concord, in Lewis county, Kentucky; and Springdale, in Mason county. At Sunset, in Fleming county, it occurs at the upper *Hebertella insculpta* horizon. At Owingsville, in Bath county, it occurs just below the *Dinorthis subquadrata* horizon. West of Spencer, in Montgomery county, it occurs associated with *Dinorthis subquadrata*, near the base of the Liberty.

In Indiana, *Leptaena richmondensis* occurs in the lower part of the Liberty, especially a short distance above the upper *Hebertella insculpta* horizon, as far south as half a mile south of Olean, in the southeastern part of Ripley county. At Madison,

in Jefferson county, most specimens occur immediately beneath the *Hebertella insculpta* horizon. At the mouth of Bull Creek, in Clark county, *Leptaena* is found associated with *Dinorthis subquadrata*, in the Liberty member.

The distribution of *Leptaena richmondensis* in the upper part of the Liberty and the lower part of the Whitewater has not been determined with care, but the fact that field notes do not contain any mention of *Leptaena* at this horizon suggests that the species probably is rare here, and possibly is even absent.

At the top of the Whitewater bed, *Leptaena richmondensis* is present at Spring Hill, near the home of Harley Wilkinson, in the eastern part of Warren county, Ohio; 1 mile southeast of Fair Haven, in Preble county; along Elkhorn Creek, 3 miles south of Richmond, in Indiana, and at the top of the exposures in the western part of the city of Richmond itself.

The occurrences of *Leptaena richmondensis* on Painter Creek, east of Westport, in Decatur county, and on Honey Creek, in the northwestern corner of Ripley county, in Indiana, are interpreted as of Whitewater age, above the Saluda horizon, but the stratigraphy needs further study.

At Moores Hill, in Dearborn county, *Leptaena richmondensis* occurs from the upper *Hebertella insculpta* horizon at various intervals down to 30, and possibly 40 feet below this level. The exact interpretation of the section, however, needs further study. It may be that the upper or Blanchester division of the Waynesville member thickens westward. At Clarksville, in Clinton county, Ohio, the thickness from the base of the lower *Hebertella insculpta* zone to the base of the upper *Hebertella insculpta* zone is about 28 feet. At Jacksonburg, in Butler county, the interval is 35 feet. Southwest of Brookville, in Franklin county, in Indiana, *Dinorthis carleyi* occurs at the base of the Blanchester division 38 feet below the upper *Hebertella insculpta* horizon. This makes it possible that at Moores Hill the lowest layers containing *Leptaena richmondensis* may belong near the base of the Blanchester division.

Leptaena is common at all of the localities in Franklin and Union counties, in Indiana, at which *Dinorthis carleyi* occurs in the Waynesville member, presumably at the base of the Blanchester division, since the latter unquestionably is the upper horizon at which *Dinorthis carleyi* is found in Ohio, where the presence o

Hebertella insculpta at the *Dinorthis carleyi* horizon fixes the position of the latter.

Leptaena richmondensis occurs in the Waynesville member also at Dismukes, 4 miles north of Gallatin, in Tennessee. The species in the Fernvale member, in the Tennessee River Valley of western Tennessee, in the Mississippi River Valley, and westward, is *Leptaena unicosta*, although *Leptaena rhomboidalis* is listed from the Orchard Creek shales, in Calhoun county, Illinois, and from the Maquoketa of Iowa.

In determining the source of *Leptaena richmondensis*, geographically, it should be noted that it is associated in the Arnheim with *Dinorthis carleyi* and *Rhynchotrema dentata*, and apparently was brought in from the same source as that which furnished these species, arriving a relatively short time before the latter. Again, in the Waynesville member, *Leptaena richmondensis* makes its appearance before *Dinorthis carleyi*, the latter coming in at the lower *Hebertella insculpta* horizon, at the base of the upper or Blanchester division. *Rhynchotrema dentata* is seen farther up in the Blanchester division. *Strophomena concordensis* comes in at the close of the Arnheim, a considerable distance above *Leptaena richmondensis*, *Dinorthis carleyi*, and *Rhynchotrema dentata*. The corresponding species, *Strophomena nutans*, comes in 12 feet above the base of the Blanchester division, a considerable time later than the reintroduction of *Leptaena richmondensis* and *Dinorthis carleyi*, but before the recurrence of *Rhynchotrema dentata*. Since none of these species occur in the Mississippi Valley, they do not appear to have entered Cincinnatian areas from the west. Since *Leptaena richmondensis*, *Dinorthis carleyi*, and *Rhynchotrema dentata* are unknown in the long stretch from Drummond Island to New York State, they do not appear to have come in from the north; *Rhynchotrema neenah*, from Wisconsin and Illinois, is not sufficiently similar to *Rhynchotrema dentata* to indicate the origin of this species from the northwest. Connection with the St. Lawrence Valley and the east appears to be shut off by shaly and sandy Richmond deposits, practically unfossiliferous. This leaves chiefly a southern origin for that part of the Arnheim fauna here under discussion, notwithstanding the fact that the nearest relative to *Dinorthis carleyi* is *Dinorthis retrorsa*, of Wales.

Plectambonites curdsvillensis, sp. nov.

(*Plate X, Figs. 15 A, B*)

In the specimens from the Curdsville bed, at Glenn Creek Station, in the northwestern edge of Woodford county, the interior of the brachial valve is thickened near the anterior and lateral margins, the thickening beginning about 2 or 2½ mm. from the margin and extending to within 1 mm. of the latter. However, between the thickened border and the margin of the valve, the shell is much thinner and is traversed, in the same direction as the radiating striae, by a series of short, vascular grooves, of which about 7 occur in a width of 2 mm. The linear callosity adjoining the hinge-area is narrower than in *Plectambonites rugosa*, and meets the thickened border, described above, rather abruptly. The two median ridges separating the two adductor areas usually are prominent and sharp, as in the less mature stages of *Plectambonites rugosa*, although sometimes thickened anteriorly. The lateral outlines of the adductor areas tend to be crescentic. Six or seven radiating striae occur in a width of 1 mm., with every fourth striation slightly more prominent.

Plectambonites plicatellus, Ulrich[23]

(*Plate I, Figs. 8 A, B*)

The chief characteristics of this species are its small size and coarse radiating striations. The shells attain a width of about 5 mm., and 5 relatively strong and prominent striae occur in a width of 1 mm. The delthyrium is wide, the sides forming an angle of 120 degrees; the lower part is occupied by the chilidium, and the upper part by the cardinal process of the opposite valve. The species is characteristic of the Fulton horizon, at Cincinnati, Ohio.

[23] *Journal, Cincinnati Soc. Nat. Hist.*, vol. i, p. 15, 1879.

Plectambonites rugosa, Meek[24]

(Plate I, Figs. 7 A, B, C; Plate X, Figs. 7 A, B, C, D)

The name *rugosa*, first proposed by James in a list of fossils from the Cincinnati Group, in 1871, was later changed by James to *aspera*, in the belief that the name *rugosa* was preoccupied by *Leptaena rugosa*, a view no longer tenable now that the generic name *Plectambonites* has been adopted for the species typified by *Plectambonites sericea*.

The types of *Plectambonites rugosa* were found about 150 feet above low-water mark of the Ohio River, at Cincinnati, Ohio. This would place them in the Southgate division of the Eden. A series of specimens, labelled as the types of *Leptaena aspera*, in the James collection, preserved in the Walker Museum, at Chicago University, is numbered 1085. None of this series shows the interior surface of either valve. The term *rugosa* was given not on account of the oblique wrinkles along the hinge-line but on account of the roughened surface of the general exterior surface of the valves, especially anteriorly. This roughened surface appears due to the presence of numerous very thin overlapping films of shell material. These films appear to consist of the same extremely fine, silky, fibrous material as that forming the compact body of the valves. Sometimes they are traversed by the same radiating striae as those seen on that part of the exterior surface of the valves where the films are not present. The films may be more or less discrete from one another, but in some specimens they are built up into a solid mass, resulting in a thickening of the valves exteriorly. At the exterior margin of the pedicel valve, this thickening may reach a total of fully 2 mm., and frequently the anterior, more or less vertical slope of this thickening is crossed by lines evidently corresponding to the extensions of the radiating striae. The thickening usually is confined to the anterior half or third of the valves. It may result in a succession of concentric bands, the one nearest the anterior margin being the most conspicuous. At other times, the thickening increases evenly, without any concentric banding, but, most frequently, it is more or less irregular, the films being more or less warped or

[24] *Plectambonites rugosa, Ohio Paleontology*, vol. i, p. 72; plate V, Figs. 3 *f, g, h;* 1873. *Plectambonites aspera*, James, *Cincinnati Quarterly Journal of Science*, p. 151, 1874.

broken into shreds. In most specimens no trace of these films is found, there is no thickening of the valves anteriorly, and the exterior surface is comparatively smooth except where interrupted by the stronger radiating striae. Possibly the films are produced in rapid succession by the mantle, each later film more or less crowding out of its road the earlier films, until the thicker, solid shell material of valves is produced. As a matter of fact, the films should be investigated by means of a series of thin sections, under the microscope, in order to determine their more intimate structure, before theorizing as to their origin. Shells with this structure have a considerable vertical range. They are most abundant in the Eden, ranging from the lowest strata immediately above the Fulton layer into the Southgate layer which furnished the types. Similar specimens occur also in the Waynesville and Liberty members of the Richmond, although the thickening at these upper horizons usually is less prominent. Some of the poorly preserved, silicified specimens from the Curdsville bed appear to have had a similar structure. Possibly this structure is of a more extended range, and may occur sporadically in almost any species of the genus. At any rate, it is not a constant characteristic of any species, as originally supposed by James. At least, in many specimens no trace of it remains.

The oblique wrinkles along the hinge-line, described and rather inadequately figured by Meek, occur not only in the lower and middle Eden but also in the Waynesville beds. They are not constant at any horizon, and do not characterize any species. They are likely to occur in any of the larger specimens, though specimens of medium size also occasionally show the oblique wrinkles.

Under *Leptaena aspera*, James stated that the cardinal line of the brachial valve is straight, and has a crenulated appearance, most conspicuous when held to a strong light. This crenulated appearance is not due to any unevenness of surface, either of the hinge-area or of the exterior surface of the valves. It is seen only when light is transmitted *through* the shell substance, and is most distinct in the more translucent shells. The number of wrinkles varies from 6 to 11 in a width of 3 mm. As viewed ordinarily, the wrinkles appear at right angles with the hinge-line and therefore have no connection with the oblique wrinkles seen on the exterior of the valves. They occur also when viewing the brachial valve by

means of transmitted light, although not as conspicuous as in the case of the pedicel valve. The solution of the problem is seen on examining the interior of the valves. The interior of the brachial valve is slightly thickened along the hinge-line, this thickening being narrowly linear, but increasing slightly in width toward its junction with the thickening bordering the lateral and anterior parts of the valve. In many specimens this interior thickening along the hinge-line is crossed by a series of minute transverse ridges, which, however, do not intrude upon the hinge-area. In the case of the pedicel valve, a similar series of minute transverse ridges is seen upon the linear callosity filling in the space between the hinge-area and the immediately underlying part of the shell. The shell material composing these transverse ridges is deposited by the mantle in an undulating manner, the transverse ridges forming the rising parts of the undulations, and the supposed wrinkles, seen when the shell is viewed by means of transmitted light, correspond to the depressions of the undulations. The phenomenon evidently is one dependent upon the laws of refraction of light, and is connected not with any actual wrinkling of the hinge-area or of the exterior surface, but with the undulating surface of deposition of the shell material along the linear callosities lining the interior of the valves immediately within the hinge-area. From these statements it will be noticed that the supposed wrinkles of *Plectambonites* do not originate along the line of junction of the hinge-area with the posterior line of the exterior surface of the shell, and hence can not have led up to the hollow spines along the posterior margin of *Chonetes*. Specimens showing these supposed wrinkles are more common in the Waynesville bed than in the Eden beds, so that this feature can not be used to distinguish between the two horizons. Moreover, numerous specimens do not show the wrinkling.

Among the specimens referred to *Plectambonites rugosa*, with the oblique wrinkles along the hinge-line, many are 12 mm. long and 25 mm. wide. It is specimens of this large size which occurred 150 feet above the Ohio River at Cincinnati, in the Southgate member of the Eden, and which formed the types of *Plectambonites rugosa*. However, specimens of large size occur also at the base of the Eden.

In the Waynesville member of the Richmond, *Plectambonites* is common in the lower part of the middle or Clarksville division,

from the *Orthoceras fosteri* horizon upward for a distance of 5 to 10 feet. Some of these specimens are very large, frequently reaching a width of 22 mm. These specimens show the oblique wrinkling along the hinge-line, the so-called vertical wrinkles when examined by transmitted light, and the external thickening of the shell due to the presence of more or less discrete or conjoined films, as described in the preceding lines under *Plectambonites rugosa* from the Eden beds. *Plectambonites* occurs also between the lower *Hebertella insculpta* horizon and the strata containing *Strophomena nutans* and *Strophomena neglecta*, in the lower part of the Blanchester division. It is abundant in the lower part of the Liberty member, frequently ranging upward through half of the member. It is seen again in the lower part of the Whitewater member, from 7 to 13 feet above the base, but here it is rather scarce and small.

Various attempts to distinguish the numerous specimens found in the Waynesville and Liberty members from those found in the lower and middle Eden have not proved very successful. As a rule, the delthyrium of the Liberty and Waynesville specimens is narrower, the sides forming an angle of about 67 degrees, while in the Eden specimens this angle usually is about 85 degrees, and the hinge-area is relatively lower. In the former, the three ridges formed by the posterior slopes of the cardinal process and the proximal terminations of the two crural plates, as seen through the delthyrium of the complete shell, diverge less. The median parts of the brachial valve are traversed by two diverging ridges, thickening anteriorly, and sometimes separated anteriorly by two much lower vascular ridges. On each side of the prominent pair of median ridges is an adductor scar. A low ridge, indistinct posteriorly, divides each scar into two parts longitudinally. In the specimens from the Liberty and Waynesville beds, the exterior lateral outline of the adductor areas is approximately crescentic in form, and is fairly well defined posteriorly; anteriorly the exterior half of the adductor scar converges toward the longitudinal ridge separating it from the inner half. In the specimens from the Eden beds, the anterior outline of the adductor scars tends to be more quadratic, the anterior termination of the exterior half of each scar being broader, and more in line with the anterior termination of the inner half of the same scar; posteriorly, the exterior lateral outline of the adductor scars frequently is rather indistinct.

It is doubtful whether it will be possible to make use of these distinctions between the Richmond and the Eden forms of *Plectambonites* except locally. The variations are of the lower rank to which the term *mutations* rather than *varieties,* has been applied recently. The term *Plectambonites rugosa-clarksvillensis* will serve to designate the large specimens from the lower third of the Clarkvsille division of the Waynesville bed, in Ohio and Indiana. With these specimens, those from other horizons in the Clarksville and Blanchester divisions of the Waynesville, and those from the Liberty bed, are regarded as identical.

The difference in outline from transversely elongate quadrangular to semi-elliptical frequently is shown with all intermediate stages on the same slab. All of the shells belonging to the *Plectambonites rugosa* group increase more in width than in length, when attaining a large size. The resultant outline is a matter of luxuriant environment rather than of specific change, and is shown more conspicuously by the larger specimens than by the smaller specimens.

It will be scarcely worth mentioning that these slight differences between forms found at different horizons will be found of interest more by the stratigraphical paleontologist, than by the student of biology. However, if such species as *Plectambonites sericea* are to be of any value for the closer correlation of the smaller divisions of Ordovician formations, the attempt must be made to discriminate between the smaller variations. Whether the present attempt has added anything or not, is another question.

Rafinesquina declivis, James

(Plate VIII, Fig. 10, enlarged)

An enlarged drawing of the same type specimen as that represented by Fig. 12 *C,* on plate V, in vol. XVI of this Bulletin, is here presented, in order to give a better idea of the alternation of single stronger striae with sets of two or three finer striae. The median striation is the most prominent.

Dalmanella emacerata, Hall[25]

(*Plate VIII, Figs. 3 A, B*)

Dalmanella emacerata was described by Hall in the *Thirteenth Report of the Regents of the University of New York, State Cabinet of Natural History*, page 121, in 1860, and first figured in the *Fifteenth Report* of the same series, in 1862, by Figs. 1 to 3, on plate II.

In the original description the shell is stated to be "semi-elliptical, length and width about as five to seven; hinge-line nearly equalling the width of the shell."

Fig. 1, on plate II, of the *Fifteenth Report*, represents a brachial valve 15 mm. in length and 20.5 mm. in width; the ratio of length to width being as three to four. Fig. 2 on the same plate represents a pedicel valve almost 14 mm. in length and 21 mm. in width, the ratio being as two to three.

The type specimens of *Dalmanella emacerata*, numbered 1339–2, are preserved in the American Museum of Natural History in New York City. Both are brachial valves. The one regarded as serving as a basis for Fig. 1 in the *Fifteenth Report*, is 14.5 mm. in length, and 20.8 mm. in width. The dimensions, therefore, agree very well with the ratio of five to seven, and the outline is sufficiently near that presented by Fig. 1 to have served as a basis of this figure.

The chief difference between the specimens typified by Figs. 1 and 2 of the *Fifteenth Report* lies in the more quadrate outline of that typified by Fig. 1, and the more elliptical outline of that represented by Fig. 2. Specimens of the first type are figured in the *Bulletin of Denison University*, vol. XIV, page 213, and plate IV, Fig. 1, as *Dalmanella emacerata-filosa*. They evidently represent typical forms of *Dalmanella emacerata*, and the varietal name *filosa* should be dropped. Specimens of the second type are represented by Fig. 5 on plate VII of the same volume, page 322, as *Dalmanella brevicula*.

In typical *Dalmanella emacerata*, there is a tendency toward the greatest width lying near the line across the middle of the shell. In typical *Dalmanella emacerata-brevicula*, the greatest width of the shell lies distinctly posterior to a line across the middle of

[25] *Thirteenth Regents Report, Univ. of New York*, p. 121, 1860.

the shell. In typical *Dalmanella emacerata* there is a tendency toward a more angular postero-lateral outline. In *Dalmanella emacerata-brevicula* this part of the outline usually is more rounded, but in neither case is this feature sufficiently constant to be of diagnostic value.

In the type of *Dalmanella emacerata*, Hall, as preserved in the American Museum of Natural History, many of the finer striae are more or less obscured by the clay which still adheres to the specimen, but sufficient evidence is presented under a lens to make it certain that the striae of the type are very fine and close, as in the specimen figured under the name *Dalmanella emacerata-filosa*. Near the antero-lateral margins, 16 to 17 striae occur in a width of 5 mm. It is now evident that typical *Dalmanella emacerata* must not be identified with the much more coarsely striated form found in the Fulton bed, 2 feet above the crinoidal top of the so-called Trenton rock as exposed in the First Ward, in Cincinnati, Ohio. These specimens from the Fulton bed, for which the name *Dalmanella fultonensis* (*Bull. Denison Univ.*, vol. XIV, plate VII, Fig. 1) is here proposed, are much more coarsely striate, having only about 10 striae in a width of 5 mm. In coarseness of striae they are more nearly allied to the *Dalmanella multisecta* type of shell.

The horizon of typical *Dalmanella emacerata* is in the Southgate bed, about 160 feet above low-water in the Ohio River, at Cincinnati, Ohio. The lower forms, about 60 feet above the base of the Eden, are somewhat more coarsely striated.

Dalmanella emacerata-brevicula occurs at the same horizons and the value of this varietal designation is still in doubt. The types occur in the Southgate bed. Both forms range up into the lower part of the McMicken bed.

Hebertella subjugata, Hall

(*Plate VIII, Fig. 6*)

In this number of the Bulletin a view of another one of the types of *Hebertella subjugata* is added to that already published on plate II of vol. XVI of this Bulletin. This second type was illustrated by Fig. 1 *N*, on plate 32 *C*, of the *New York Paleontology*, vol. I. It is a less finely striated specimen, and similar specimens are common in the Fairmount and Bellevue

beds at Cincinnati, Ohio. As a matter of fact, they have a considerable vertical range, and form what might be called a museum species, where forms are at times discriminated that can not be kept distinct in the field. *Strophomena subtenta* presents similar difficulties.

Plectorthis fissicosta, Hall

(*Plate VIII, Fig. 4*)

A figure of the pedicel valve of the type specimen, preserved in the American Museum of Natural History, is added to those of the brachial valve of the same specimen published on plate IV, in vol. XIV of this Bulletin. This valve is crushed centrally, but the features are not obscured.

Austinella scovillei, Miller[26]

(*Plate VIII, Figs. 8 A, B, C*)

In the original description of this species, it is stated that the types were collected near Lebanon, Ohio. As a matter of fact, however, they were found about 7 miles northeast of Lebanon, at a locality then known as Freeport, but now called Oregonia. Here they occur 5 feet below the upper *Hebertella insculpta* horizon, in the upper part of the Blanchester division of the Waynesville member of the Richmond. The present location of the types figured by Miller is unknown, but the species is readily identified, and a number of specimens from the James collection, preserved in the Walker Museum, at Chicago University, are here figured. Some of these are labelled as coming from Oregonia, others as having been found at Blanchester, evidently at the same horizon. The exposures at Lebanon belong to the Fort Ancient division of the Waynesville.

Austinella scovillei is regarded as the genotype of the proposed group, *Austinella*. Figs. 8 *B*, and *C*, on plate VIII of this Bulletin, illustrate the narrow, rectangular muscular area of the pedicel valve, characteristic of this group. From the anterolateral angles of this area, branching vascular ridges diverge, only indistinctly indicated in the accompanying figures.

[26] *Journal, Cincinnati Soc. Nat. Hist.*, vol. V, p. 40, 1882.

An interior of a brachial valve is found in the collection of Dr. George M. Austin. Its hinge-area is flat, inclined at an angle of about 20 degrees with the plane passing parallel to the margins of the valve. Cardinal process of medium width, with a narrow groove down the middle posteriorly. A low median elevation extends from the thickened area between the crural plates forward between the areas where the muscle scars should be. Deep and broad dental sockets; no evidence of an extension of the crural plates beyond the anterior margin of the hinge-area.

Austinella kankakensis, from the Richmond at Wilmington, Illinois, is described by McChesney as having 60 to 70 radiating striae. *Austinella whitfieldi,* from the Richmond at Spring Valley, Minnesota, occurs in the same division of the Richmond, and probably is specifically identical with *Austinella kankakensis.* From these species, *Austinella scovillei* differs only in the smaller number of radiating plications.

Austinella whitfieldi, Winchell[27]

(Plate VIII, Fig. 9)

A figure of the quadratic muscular area is presented on plate VIII, Fig. 9. It is more rectangular than in the case of the figures published hitherto, and was secured by photographing a clay cast taken from a sharp natural cast of the interior of a pedicel valve, belonging to the group numbered 8114, in the Gurley collection, preserved in the Walker Museum of Chicago University.

Clitambonites multistriata, sp. nov.

(Plate X, Fig. 12)

Three-quarters of a mile north of the railroad station at Danville, Kentucky, the richly fossiliferous zone belonging to the Faulconer division of the Perryville bed consists of fine-grained whitish limestone. Not all of this section, however, consists of fine-grained limestone. Some of the layers are distinctly granular, but all of the granular layers are distinctly whiter in color than any belonging to the Paris limestone, beneath. In these

[27] *Ninth Ann. Rept. Geol. and Nat. Hist. Survey, Minnesota,* p. 115, 1881. *Minnesota Geol. Survey,* vol. iii, p. 437, 1893.

whitish limestones, a variety of *Clitambonites* with finer and more numerous radiating striae than usual is present. The specimens are broader and much more finely striated than *Clitambonites diversus*, Shaler (plate X, Fig. 13). They probably are more closely related to *Clitambonites americanus*, Whitfield, from the Prosser limestone of Wisconsin and Minnesota, than to the Anticosti species; however, these Danville specimens are more finely striated and broader also than specimens from the Prosser horizon. The distinction is one likely to appeal only to the stratigraphical paleontologist.

Orthorhynchula linneyi, James

(*Plate XI, Fig. 5*)

The Upper Birdseye beds of Linney included both the fine-grained, in part dove-colored limestone overlying the Paris bed, in Mercer and Boyle counties, Kentucky, and also the still higher strata, containing *Stromatocerium, Dinorthis ulrichi, Strophomena vicina, Hebertella frankfortensis* and *Rhynchotrema inaequivalve*, for which the term Cornishville bed was proposed recently. The Perryville member includes that part of the Upper Birdseye limestone of Linney which lies below the Cornishville limestone. Usually it may be divided into two parts. The upper, between 5 and 8 feet thick, is very fine-grained, more or less dove-colored, with small, translucent spots, and with relatively few fossils. The lower part, from 15 to 20 feet in thickness, frequently is darker, and softer, and more fossiliferous. About 1 mile west of Nevada, these lower layers are richly fossiliferous, and are supplied with silicified gasteropods and excellently preserved valves of *Cyrtodonta*. *Tetradium* is widely distributed at this horizon. Farther eastward, especially between Danville and Harrodsburg, along the railroad, this lower part of the Perryville is even more richly supplied with silicified fossils, and the rock is whiter, and less distinguishable from the so-called dove-colored limestones at the top. Should any separate designation for the lower layers with the silicified fossils be desirable, the term Faulconer limestone will serve. The Perryville limestone thins out northward and northeastward before reaching the Richmond sheet of the United States Geological Survey, from which the Flanagan chert was described. At Flanagan, the Flanagan chert

lies *above* the *Dinorthis ulrichi–Strophomena vicina* horizon, regarded as corresponding to the Cornishville limestone.

Excellent specimens of *Orthorhynchula linneyi* are found in a very fine-grained, white limestone, belonging to the Perryville horizon, about 4 miles north of Versailles, Kentucky. The locality is reached by going from Wallace nearly 1½ miles west and then about the same distance southward, to a turn in the road. The exposures are poor, but loose blocks dragged out from the fields west of the road present beautiful specimens of *Orthorhynchula*, together with *Tetradium* and other fossils usually found in the lower part of the Perryville bed, such as *Isochilina jonesi*. In the specimens of *Orthorhynchula*, the beaks of both valves are less incurved than in the Catheys or Fairmount specimens, so that the delthyrium is better exposed.

Trematospira granulifera, Meek[28]

(Plate VIII, Fig. 5, enlarged)

Pedicel valve with shallow sinus. Median plication narrow, bifurcating, 2 mm. from the beak, into two narrow branches, which at the anterior margin are 0.7 mm. distant from each other. On each side of the resulting median pair of plications there is a distinctly larger plication, forming the sides of the sinus posteriorly, but lying within the depression of the sinus anteriorly. The axes of this second pair of plications are about 3 mm. distant from each other at the anterior margin of the valve. The third pair of plications, counting from the median pair outward, forms the sides of the sinus anteriorly. Their axes are 6 mm. distant from each other anteriorly. Near the beak, all the plications, except the median bifurcating one, are approximately of the same size, but anteriorly they differ considerably. The width of each of the two branches of the median plication is 0.8 mm. The first plication on each side of this median pair is from 1 to 1.2 mm. wide. The second plication on each side, counting from the median pair, varies from 2.2 to 2.4 mm. in width. The third, fourth, and fifth plications on each side also are of considerable width, and, together with the second pair,

[28] *Proc. Acad. Nat. Sci.* Philadelphia, 1872, p. 318. *Ohio Paleontology,* vol. i, p. 128, 1873.

form the prominent, sharp, angular plications of the valve. The sixth plication, near the hinge-line on each side, is inconspicuous. It is impossible to determine from the specimen whether the opening at the beak is due to breakage or not. The beak of the pedicel valve laps over that of the brachial valve, and hides the latter.

Brachial valve with median plication narrow, beginning 2 mm. from the overlapping beak of the pedicel valve, and remaining narrow as far as the anterior margin, where its width is 0.7 mm. The first and second plication, on each side of this median one, are 1 mm. wide, and belong to the median fold, so that this fold bears 5 plications, while the corresponding median sinus of the pedicel valve contains only 4 plications. The ridges of the exterior plications on the fold of the brachial valve are 4 mm. distant from each other, and their exterior sides slope downward into the deep groove separating the second from the third plication. The third, fourth, and fifth pairs of plications are prominent, and are separated by deep wide grooves. The sixth plication on each side, counting from the median one, is considerably less prominent, though considerably more prominent than the sixth plication of the pedicel valve.

Not the slightest trace of a hinge-area is seen on the brachial valve, and practically none in the case of the pedicel valve.

Surface with low, and rather distant, concentric lines of growth. Minute granules, probably connected with a minutely porous structure of the shell. Much larger granules, rather irregularly arranged, but more frequently approximately in line with the concentric lines of growth.

Length, 10 mm.; width, 13 mm.; depth or thickness, 7.2 mm.

The type, numbered 1622, is preserved in the Dyer collection at Harvard University.

The features which suggest the propriety of referring this species to *Trematospira*, in the absence of all knowledge of the interior, are the close enfolding beak of the pedicel valve, obscuring the view of the deltidial plates, and the numerous minute granules, suggesting an abundantly punctate structure for the shell; also the presence of a fairly distinct median fold and sinus. It seems so improbable that any species of *Trematospira* could occur in Cincinnatian strata, that I have suspected for some time that eventually *Trematospira granulifera* would turn out to be an

aberrant specimen of some well known species, for instance, *Trematospira gibbosa*, from the Hamilton of New York. The specimen actually found by the collector at Cincinnati might have been a specimen of *Zygospira cincinnatiensis*, but in the course of time, by a mixture of labels, the *Trematospira* was regarded as Cincinnatian. To be sure, *Trematospira gibbosa* is figured as having only three plications on the fold and two in the sinus, but the type of *Trematospira granulifera* is supposed to be an aberrant specimen. Although intercalated narrow median plications are to be expected in *Rhynchospira* and *Homoeospira* rather than in *Trematospira*, the former genera have no broad median fold and sinus, similar to that of some species included in *Trematospira*.

Lingula procteri-versaillesensis, var. nov.

(*Plate X, Figs. 8 A, B*)

Lingula procteri was described by Ulrich from specimens which passed into the possession of Professor Schuchert, and representative specimens were figured by Hall and Clarke in the *Paleontology of New York*, vol. VIII, part 1, plate I, Figs. 5 and 6. These specimens were obtained at Bank Lick, several miles south of Covington, Kentucky, in strata which stratigraphically belong below the Fulton layer, and therefore below the Eden. In these specimens the concrete laterals of the brachial valve are represented by semi-elliptical areas bordering the median septum, and are traversed by slightly curved, subparallel lines, beginning at the median septum and directed obliquely backward, toward the postero-lateral margins of the muscular areas. Anteriorly, there is a narrow heart-shaped area representing the anterior laterals. In the pedicel valve, the sides of the median septum are rather strongly divergent, and terminate near the center of the valve. The concrete laterals, bordering the median septum, are cuneiform in shape, and, together with the median septum, are bounded anteriorly by a crescentic line from which a number of short lines diverge radially, as in *Lingula vanhorni*.

In the Paris division of the Lexington limestone, within the city limits of Versailles, Kentucky, a species of *Lingula*, which is practically identical with *Lingula procteri* in outline, is common. The exact horizon is 20 feet below the base of the arch of the

concrete bridge crossing the railroad from Versailles to Frankfort, and approximately 20 feet above the *Strophomena vicina* horizon. In the brachial valve of these specimens there is a very narrow and very low median septum. In a specimen 18 mm. in length, this septum is most distinct 11 mm. from the beak. A small obliquely-oval muscular scar is found on each side of the septum. The inner edges of these scars are about half a millimeter distant from the median septum, and lengthwise they extend from 9 to 10.5 mm. from the beak. Their longest diameter is directed toward the antero-lateral outlines of the shell. They represent, apparently, the central scars at the anterior end of the concrete lateral areas, but there is no trace of semi-elliptical concrete laterals, crossed diagonally by subparallel striae, as figured by Hall and Clarke in the case of *Lingula procteri*, although specimens showing the interiors of the brachial valves are not rare. Anteriorly, the median septum can be traced in a much fainter form as far as 13.5 mm. from the beak. This part of the septum separates the rather narrow anterior lateral scars. In the interior of the pedicel valve, there are two very narrow and very shallow grooves, limiting the very low and broad median septum. At a distance of 8 or 9 mm. from the beak, this septum attains a width of about four-fifths of a millimeter, and in some specimens only two-thirds of a millimeter. There is no trace of any other structure. These probably are the specimens to which Ulrich refers in his original description of *Lingula procteri*, when he states that this species ranges from the middle beds of the Trenton in central Kentucky to about 50 feet above low-water mark in the Ohio River at Covington, Kentucky. Considering the fact that most species of *Lingula* have been erected upon variations in the outline of the shell and upon the surface ornamentation, the proposal of a new name based upon interior characteristics can not expect to find welcome; nevertheless, if the discrimination proves an accurate one, it must stand. Science can not profit by the failure to discriminate between *Lingula procteri* and *Lingula versaillesensis*, if the distinctions here pointed out prove to be constant and to belong to different horizons

The shell substance of *Lingula versaillesensis* is very white. The exterior is nearly smooth, and is ornamented by very faint, concentric, broad, flat striations. There is no trace of radiate lines

on the exterior surface, although the interior frequently is marked anteriorly by very fine striae which are slightly divergent and would be called radiate if they extended farther back. The largest specimens attain a length of 19 mm. In these specimens the thickness of the shell equals 4 mm., the valves being equally convex. In width, the specimens vary from 12.5 mm. to 15 and even 16 mm. There is a resultant variation in outline, the former being ovate-oblong, and the latter more broadly ovate in outline. The difference obviously is one of age, the older shells becoming rapidly broader anteriorly but not postero-laterally. For a length of about 7 or 8 mm. the lateral outlines are but slightly convex. Posterior to this part of the outline, the sides converge more rapidly to the rapidly-rounded outline at the beak, and anteriorly, the antero-lateral outline also is rather strongly rounded, compared with the moderate convexity of the anterior margin. The shell is rather evenly convex within the limits of the dimension stated. Even anteriorly the thickness of the shell is fairly well maintained to within 5 or 6 mm. from the anterior margin.

Helicotoma brocki, sp. nov.

(Plate X, Fig. 11; Plate XI, Fig. 3)

Helicotoma brocki belongs to the group of species typified by *Helicotoma planulata,* in which a series of revolving striae is found on the lower half of the outer side of the whorls of the shell. These revolving striae, however, are much stronger than in *Helicotoma planulata,* and in consequence, the lower half of the whorl appears more protuberant than in the latter species. There are five revolving striae; of these, two occupy the most prominent part of the lower half of the whorl, with the striation above and that below of equal size and an equal distance apart. The fifth striation is less prominent; it forms the outer edge of the flattened base of the shell, and the distance between it and the striation immediately above is less than between the other striae. The under side of the whorls is strongly flattened or slightly concave, with a rise of the surface at the margin of the umbilicus. Transverse striae very fine, but distinctly seen under a lens. On the lower surface of the whorls they form an angle of about 50 degrees with the outer margin; on the outer sides they form an angle of about 30 degrees with the perpendicular; and on the upper side,

they turn from the marginal notch ridge strongly toward the apertural end for a short distance and then approach the inner edge of the whorls at an angle of about 55 degrees. The umbilical slopes are steep, departing only about 10 degrees from the vertical.

The type specimen was found 35 feet below the margin of the hill south of Kagawong, on Manitoulin Island, associated with *Strophomena sulcata*, *Strophomena neglecta*, and *Strophomena huronensis*, near the base of the Richmond section. Another specimen was found a short distance southward, at the Kagawong Falls.

Fifteen feet below the base of the Clinton limestone, along Elkhorn Creek, 3 miles southeast of Richmond, Indiana, a specimen of *Helicotoma* was found associated with *Conocardium richmondensis*, *Beatricea undulata*, *Columnaria alveolata*, *Columnaria vacua*, and some species of *Ischyrodonta*. In the immediately overlying part of the section, 3 feet thick, *Ischyrodonta decipiens* is abundant. Eleven feet below the Clinton, *Tetradium* and *Stromatocerium* occur. *Ischyrodonta* is seen again at 7 feet below the Clinton. These strata form the upper part of the Elkhorn member of the Richmond, the base occurring 40 feet below the Clinton, overlying beds containing *Strophomena retusta*; 15 feet lower, *Strophomena sulcata*, *Leptaena richmondensis*, *Dinorthis subquadrata*, *Rhynchotrema dentata*, and other Whitewater fossils occur.

The species of *Helicotoma* (plate X, Fig. 10; plate XI, Fig. 4), found in the Elkhorn member resembles *Helicotoma brocki* in the steepness of the upper half of the outer side of the whorls; in the marked convexity of the lower half of this side; and in the flatness of the lower side of the whorls, with a moderate concavity lengthwise on this surface. The character of the surface ornamentation of the lower, convex half of the outer surface of the whorls, however, could not be determined from the only specimen collected. All specimens seen were crushed more or less vertically. None were found resembling *Helicotoma marginata*, Ulrich, described from Elkhorn Falls, and evidently from the same locality and horizon as the form here illustrated. The type of *Helicotoma marginata*, numbered 45830, is preserved in the U. S. National Museum, at Washington. The lateral and umbilical sides of the specimen are not exposed. To me, the specimen appeared crushed, as though the second last volution had been pushed up

and over the last volution, thus doing away with the winged idea. Under these circumstances, I should prefer to wait for a specimen showing the remainder of the shell before admitting the presence of a broad, lateral flange.

Orthoceras tyronensis, sp. nov.

(*Plate X, Figs. 5 A, B*)

In the Tyrone bed at High Bridge, Kentucky, between 24 and 29 feet below the base of the green clay at the top of the formation, the rock is richly fossiliferous. Here the following species of *Orthoceras* is found.

Orthoceracone with circular section, with the apical angle varying from 6 to 10 degrees. On one fragment, 38 mm. in length, the diameter at the larger extremity is 11 mm., and 6.5 mm. at the smaller end. The septa are moderately concave, about 6 occur in a length of 6.5 mm., where the diameter of the shell is 7 mm., the siphuncle at this point is linear in form and about two-thirds of a millimeter in diameter.

The surface of the shell probably is smooth, but in all of the specimens at hand it is covered by a papillose layer, resembling the encrusting growths to which Parks recently has applied the term *Dermatostroma*. This covering sometimes attains a thickness of half a millimeter in specimens 7 mm. in diameter. Many of the papillae are discrete, but frequently they are more or less elongate longitudinally, and coalesce into longer or shorter ridges, which sometimes are strong and bold, considering the small diameter of the shells. For this covering, regarded as an encrusting growth, the term *Dermatostroma tyronensis* is suggested.

Orthoceras tyronensis, with its corticose covering of *Dermatostroma tyronensis* occurs also 7 miles south of High Bridge, nearly 2 miles northwest of Bryantsville, where the road bends northward into a ravine.

Changes in Terminology

For *Schizonema* substitute *Schizoramma*. Type: *Schizoramma fissistriata*. *Bulletin, Denison Univ.*, vol. xiv, p. 76.

For *Bathycoelia* substitute *Pionodema*. Type: *Pionodema subaequata*, Conrad. *Bulletin, Denison Univ.*, vol. xiv, p. 221.

For *Cyclocoelia* substitute *Encuclodema*. Type: *Encuclodema sordida*, Hall. *Bulletin, Denison Univ.*, vol. xiv, p. 227.

PLATE I

Fig. 1. *Strophomena planoconvexa*. *A*, *C*, *D*, pedicel valves; *B*, brachial valve. *E*, interior view of pedicel valve. *F*, view of hinge area, copied from *Ohio Paleontology*, vol. I, plate VI, Fig. 2 *C*. Cincinnati, Ohio. Base of Fairmount.

Fig. 2. *Strophomena planoconvexa*. *A*, pedicel valve; *B*, brachial valve. One of a group of similar specimens, occurring in local collections at Wilmington, Ohio, and stated to have been collected in the Waynesville beds at Clarksville. They can not be distinguished in any manner from *Strophomena planoconvexa*, and apparently are typical basal Fairmount specimens from the vicinity of Cincinnati.

Fig. 3. *Strophomena sinuata*. *A*, pedicel valve; *B*, *C*, brachial valves. Cincinnati, Ohio, from the middle part of the Fairmount.

Fig. 4. *Strophomena sulcata*. *A*, *B*, brachial valves, differing in the coarseness of the radiating striae; *C*, interior of pedicel valve. *A* is much more sulcate along the anterior edge than is indicated by the figure. Dutch Creek, 4½ miles northwest of Wilmington, Ohio. Near top of Whitewater member.

Fig. 5. *Leptaena gibbosa*. *A*, *B*, pedicel valves; radiating striae too fine to be indicated by the figure. *C*, interior view of brachial valve. Cincinnati, Ohio. Economy member of Eden. Type specimen, number 1114, James collection, Walker Museum at Chicago University.

Fig. 6 *A*. *Leptaena richmondensis-precursor*. Pedicel valve. Arnheim, Ohio. Arnheim member.

Fig. 6. *B*, *C*. *Leptaena richmondensis*. *B*, pedicel valve; *C*, brachial valve. Madison, Indiana. Waynesville member.

Fig. 7. *Plectambonites rugosa-clarksvillensis*. All specimens nine-tenths of natural size. *A*, *B*, brachial valves; *C*, pedicel valve. Concord, Kentucky, from lower part of Liberty member.

Fig. 8. *Plectambonites plicatellus*. *A*, a group of shells, some of them open but with the valves still attached. *B*, enlarged 5 diameters, with the brachial valve at top of figure. Copied from *New York Paleontology*, vol. VIII, part I, plate XV *A*, Figs. 34, 35.

Fig. 9. *Strophomena millionensis*. *A*, *B*, brachial valves; *C*, pedicel valve. An eighth of a mile west of the tunnel west of Million, Kentucky. Near the base of the Eden exposures in that part of Kentucky.

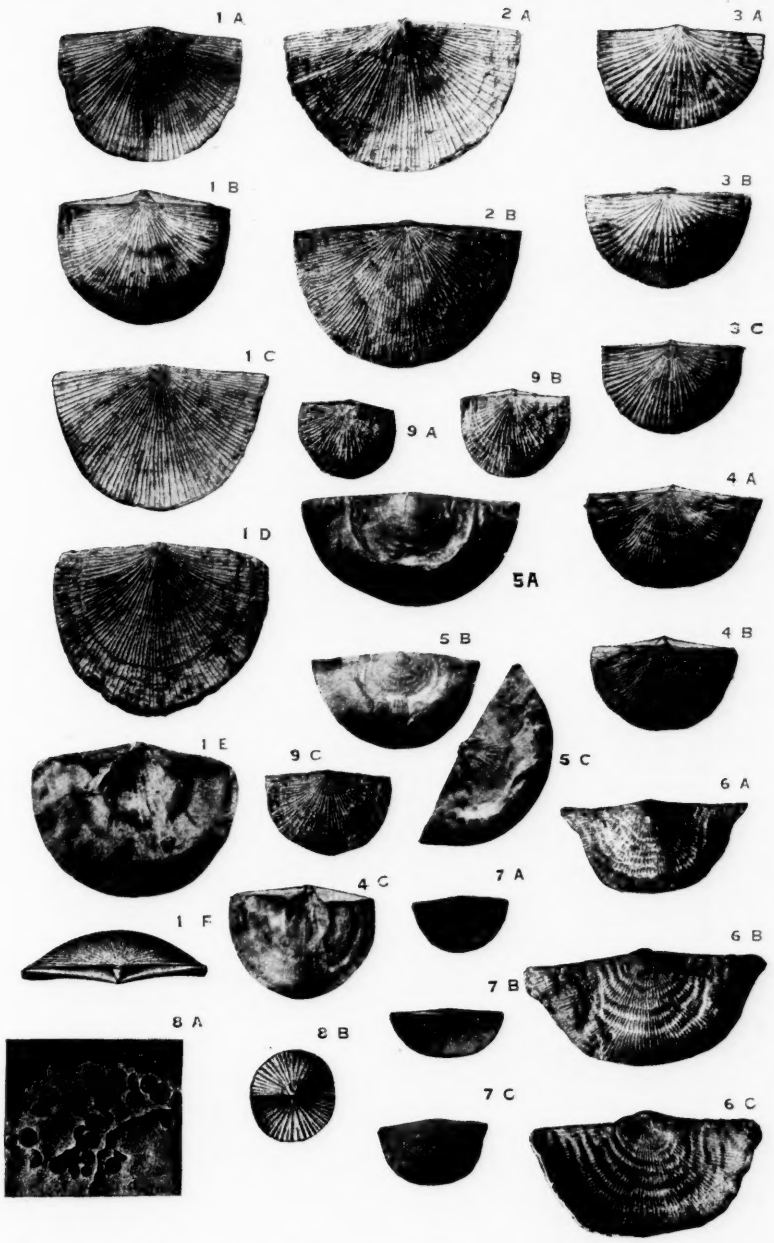

1 A
2 A
3 A
1 B
2 B
3 B
3 C
1 C
9 B
9 A
4 A
1 D
5A
5 B
4 B
1 E
9 C
5 C
6 A
4 C
7 A
1 F
6 B
7 B
8 A
8 B
7 C
6 C

PLATE II

Fig. 1. *Strophomena hallie*. *A*, brachial valve; *B*, interior of brachial valve; *C*, interior of fragment of pedicel valve; types, number 8848, Faber collection, in Walker Museum at Chicago University; Columbia Avenue, Cincinnati, Ohio, Southgate member of the Eden. *D*, pedicel valve; Limestone Creek, southeast of Maysville, Kentucky, in Southgate member. *E*, interior view of pedicel valve; in railroad cut, east of home of George Million, over a mile southeast of Million, Kentucky, at the top of the Southgate member, immediately below the Paint Lick member of the Eden.

Fig. 2. *Strophomena hallie*, variety. Apparently only an aberrant, triangular form presented by a single individual. Brachial valve. Near base of Eden as exposed west of tunnel, 1 mile west of Million, Kentucky.

Fig. 3. *Strophomena higginsportensis*. *A*, *B*, pedicel valves, interior views. See also plate X, Fig. 4, for another view of 3 *B*. Stony Point, east of Higginsport, on Kentucky side of Ohio River. Apparently near base of Eden, but exact horizon unknown.

Fig. 4. *Strophomena maysvillensis*. *A*, *B*, pedicel valves; *C*, *D*, interiors of pedicel valves; *F*, *G*, brachial valves; *H*, *I*, *J*, interiors of brachial valves. Maysville, Kentucky. Lower part of Fairmount.

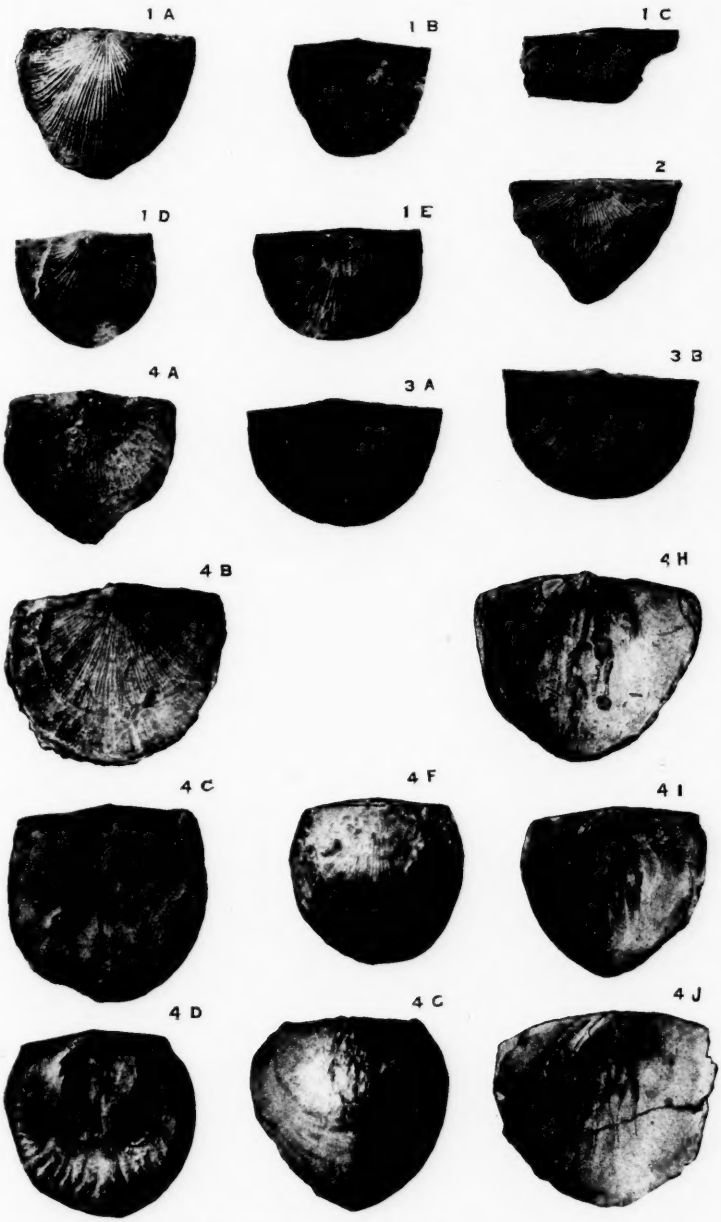
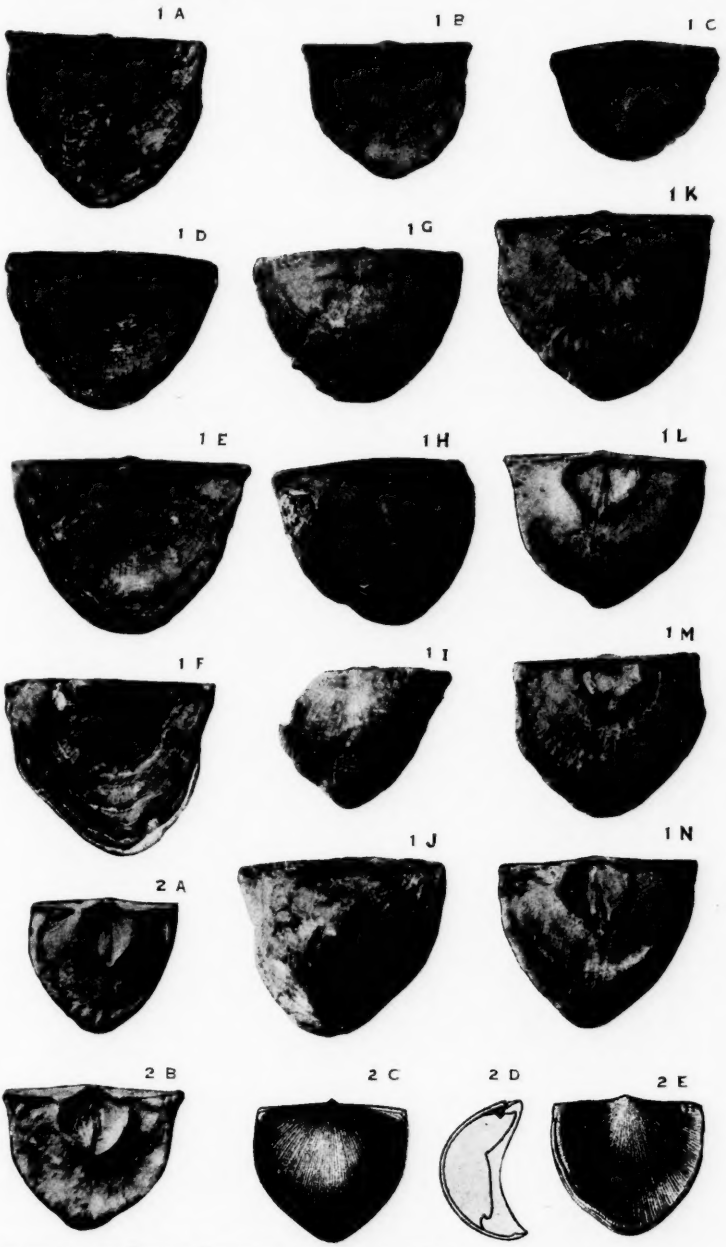

1 A
1 B
1 C
2
1 D
1 E
4 A
3 A
3 B
4 B
4 H
4 C
4 F
4 I
4 D
4 G
4 J

PLATE III

Fig. 1. *Strophomena concordensis.* *A*, *B*, *C*, *D*, *E*, *F*, pedicel valves; *G*, *H*, *I*, *J*, brachial valves; *K*, *L*, *M*, *N*, interiors of pedicel valves. Concord, Kentucky, from extreme top of Arnheim.

Fig. 2. *Strophomena nutans.* *A*, interior view of pedicel valve; Oregonia, Ohio. *C*, brachial valve; *D*, profile section with brachial valve on left and pedicel valve on right; *E*, pedicel valve; copied from *Ohio Paleontology*, vol. I, plate VI, Figs. 1 *A*, *F*, *B*; types of the species, now lost; exact locality unknown. All of these specimens came from the Blanchester division of the Waynesville.

Fig. 2 *B*. *Strophomena* resembling *Strophomena nutans.* Pedicel valve, interior view. Richmond, Indiana, at the *Rhynchotrema dentata* horizon in the Whitewater member of the Richmond group.


1 A
1 B
1 C
1 K
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1 G
1 E
1 H
1 L
1 M
1 F
1 I
1 J
1 N
2 A
2 B
2 C
2 D
2 E

PLATE IV

Fig. 1. *Strophomena elongata*. *A*, *B*, pedicel valves; *C*, *D*, *H*, *L*, interior views of pedicel valves; *I*, brachial valve; *E*, *F*, *G*, *J*, *K*, interior views of brachial valves. See also plate IX, Figs. 4 *A*, *B*, for other views of 1 *I*. Figs. 1 *A*, *B*, *I*, illustrate very well the outline of the typical specimens as seen in series number 510, James collection, Walker Museum, Chicago University, although not selected from this series of types. Fig. 1 *H*, is one of the cotypes of the James collection. *A*, *E*, *F*, *G*, *J*, *K*, are from the Waynesville member, at Madison, Indiana. *C*, *D*, *L*, belong to the Nickles collection. *C*, Waynesville member at Oregonia. *D*, Waynesville member at Madison, Indiana. *L*, Liberty member, at Richmond, Indiana.

Fig. 2. *Strophomena planumbona-gerontica*. *A*, pedicel valve; *B*, hinge-area; *C*, brachial valve. Madison, Indiana. Waynesville member. See also plate XI, Fig. 6.

Fig. 3. *Strophomena planumbona*. *A*, pedicel valve; *B*, interior of pedicel valve. Madison, Indiana. Waynesville member.

Fig. 4. *Strophomena planumbona-subtenta*. *A*, pedicel valve; *B*, *C*, brachial valves; *D*, interior of pedicel valve. Concord, Kentucky. Liberty member.

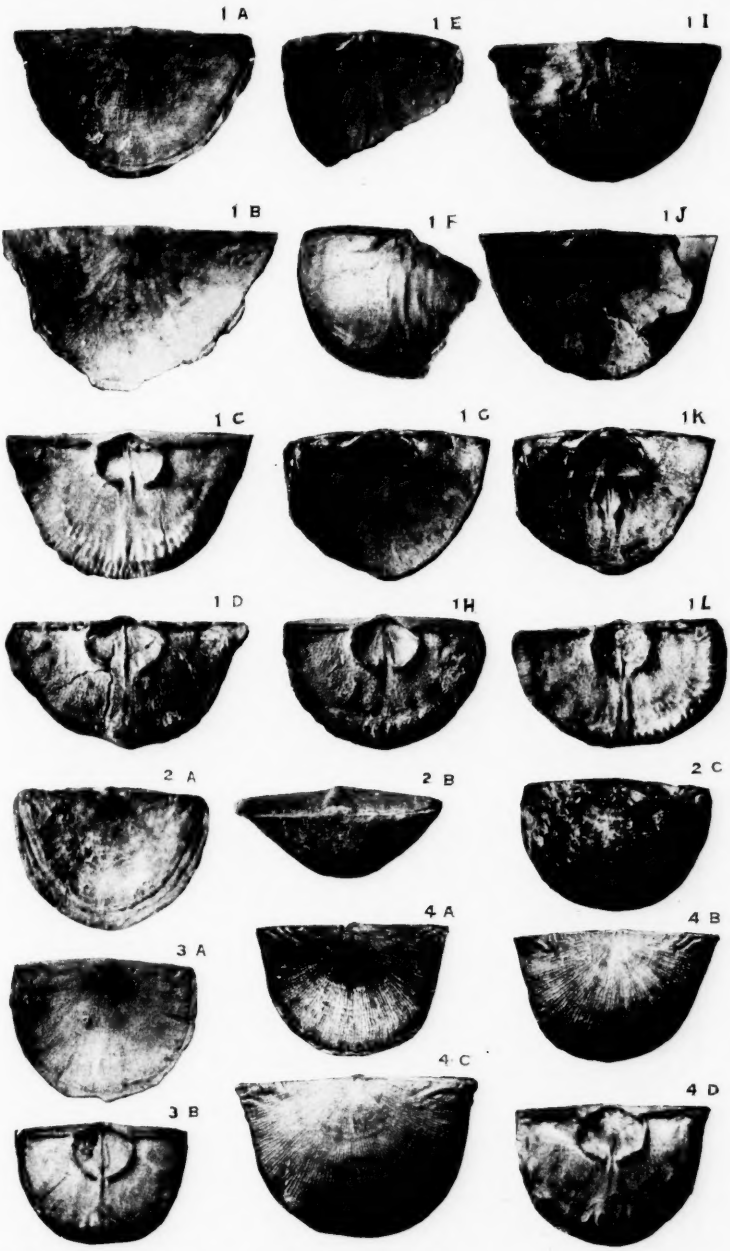

1 A
1 E
1 I
1 B
1 F
1 J
1 C
1 G
1 K
1 D
1 H
1 L
2 A
2 B
2 C
4 A
4 B
3 A
4 C
4 D
3 B

PLATE V

Fig. 1. *Strophomena neglecta*. *A*, brachial valve; *B*, pedicel valve; both from the type specimen, number 2393, in the James collection, Walker Museum at Chicago University. Specimen imperfect, missing outline supplied in wax; original outline probably nearer Fig. 3 *F*, as shown by right side of this specimen. See also plate IX, Figs. 1 *A*, *B*, *C*. Near Blanchester, Ohio. Blanchester division of the Waynesville.

Fig. 2. *Strophomena neglecta?* This is the second specimen included under number 2393, in the James collection, but probably is nearer *Strophomena vetusta-precursor* than *Strophomena neglecta*. It is evident from Meek's description, that specimens of this type were not included among the types he received from James. *A*, brachial valve; *B*, pedicel valve. Near Blanchester, Ohio. Blanchester division of the Waynesville.

Fig. 3. *Strophomena neglecta*. *A*, *B*, *C*, pedicel valves, interior views; *D*, pedicel valve, with subquadrate outline; *E*, interior view of brachial valve; *F*, exterior of brachial valve. *A*, *B*, from Oregonia; *B*, from the Nickles collection. *C*, *D*, *F*, from Clarksville, Ohio. *E*, from Moores Hill, Indiana. All from the Blanchester division of the Waynesville member.

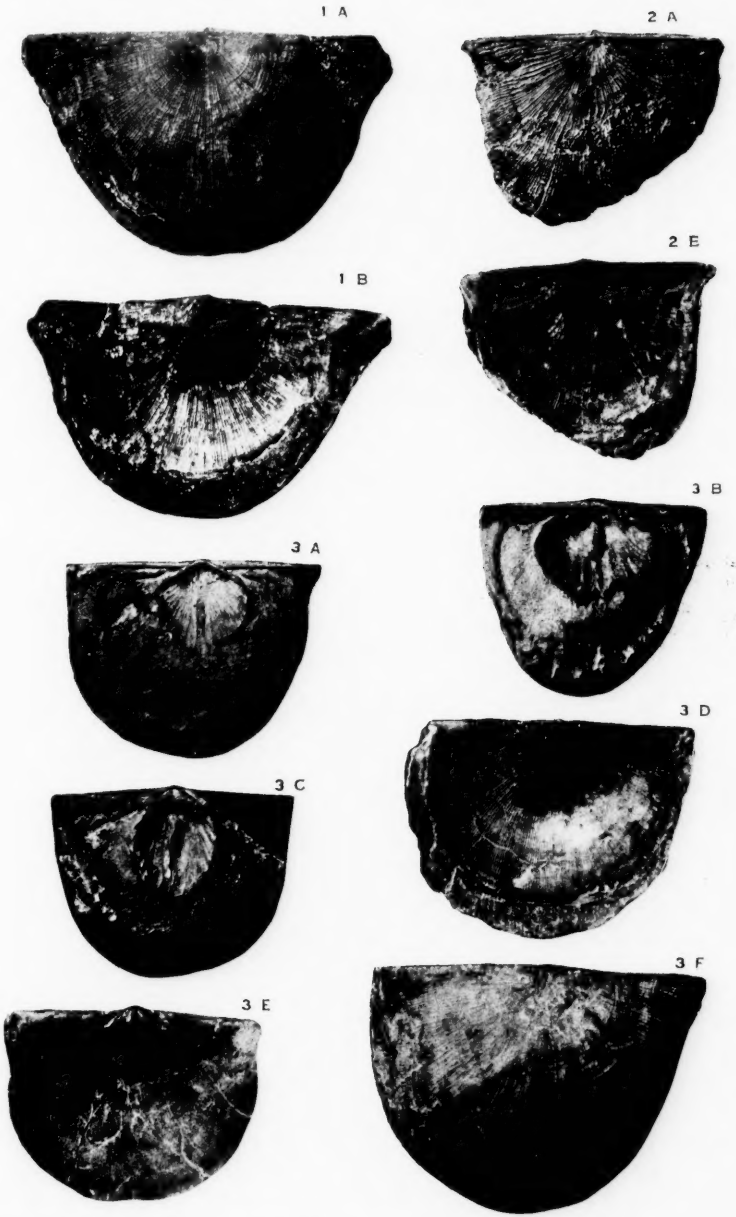

1 A
2 A
2 E
1 B
3 B
3 A
3 D
3 C
3 F
3 E

PLATE VI

Fig. 1. *Strophomena approximata.* *A*, brachial valve; *B*, pedicel valve; type specimen, number 2394, James collection, in Walker Museum, at Chicago University. *C*, brachial valve; *D*, pedicel valve, specimen in same series, but not a type. Definite horizon not known, but either Liberty or Whitewater. Dearborn county, Indiana.

Fig. 2. *Strophomena vetusta.* *A*, *C*, brachial valves; *B*, *D*, *H*, *G*, pedicel valves; *E*, interior of brachial valve; *F*, interior of pedicel valve. *B*, *C*, *D*, *E*, types, number 1567, James collection, in Walker Museum at Chicago University; labelled as coming from Blanchester, Ohio. Either from Liberty or Whitewater members. *A*, Clinton county, Ohio; *F*, Dayton, Ohio; both from Whitewater member. *G*, *H*, Cane Springs, Kentucky, from southern extension of Liberty member.

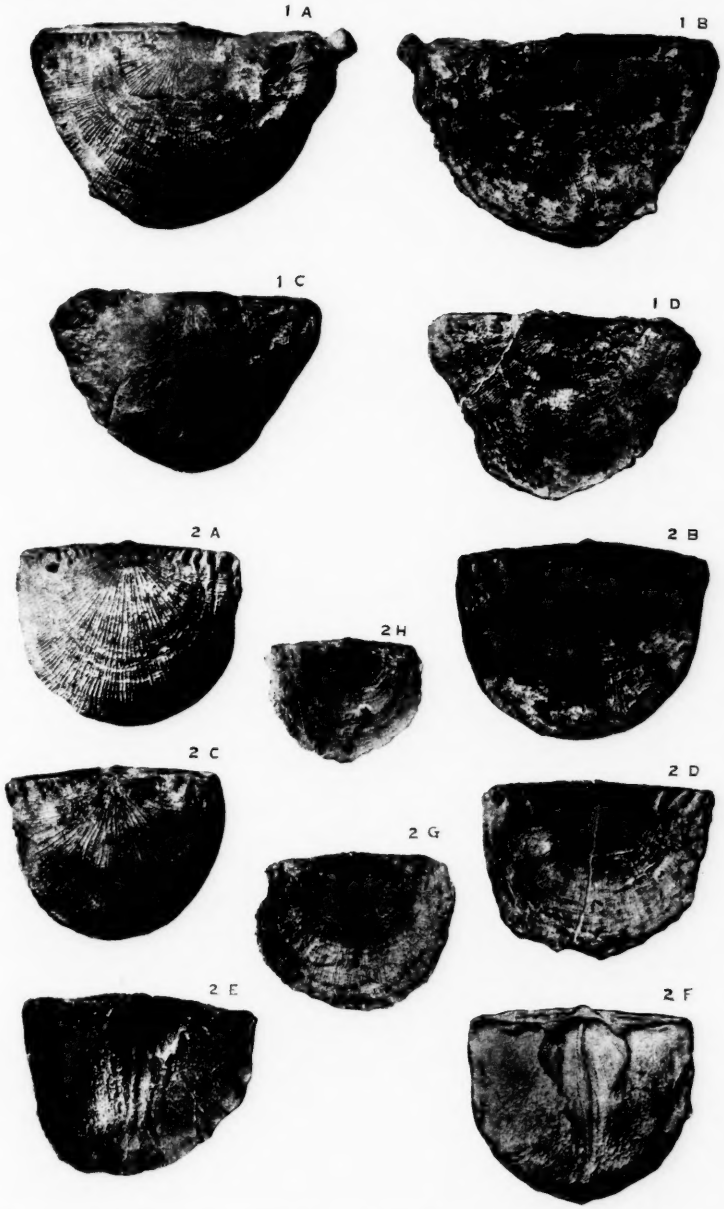

1 A
1 B
1 C
1 D
2 A
2 B
2 H
2 C
2 D
2 G
2 E
2 F

PLATE VII

Fig. 1. *Strophomena wisconsinensis*. *A*, pedicel valve; *B*, brachial valve; *C*, interior of pedicel valve. Wilmington, Illinois. Richmond group. Schuchert collection. See also plate IX, Figs. 5 *A*, *B*, *C*.

Fig. 2. *Strophomena vicina*. Pedicel valve, magnified 1.5 times. Northeast of Beckner ville, Kentucky. Paris member. See also this Bulletin, vol. XIV, plate VII, Fig. 12 *A*.

Fig. 3. *Strophomena acuta*. *A*, brachial valve. See also plate IX, Figs. 13 *A*, *B*. *B*, pedicel valve; *C*, pedicel valve; *D*, brachial valve. *A*, *B*, from Schuchert collection. *C*, *D*, from University of Minnesota collection. Spring Valley, Minnesota. Richmond group.

Fig. 4. *Strophomena planodorsata*. *A*, pedicel valve; *B*, brachial valve. Mannie clay, forming upper part of Richmond group, a quarter of a mile northeast of Fly, beyond the home of R. S. Elam. See also plate IX, Figs. 14 *A*, *B*.

Fig. 5. *Strophomena neglecta*. Interior of pedicel valve. Richmond group. Savannah, Illinois. Schuchert collection. See also plate X, Fig. 10.

Fig. 6. *Strophomena planodorsata*. Interior of pedicel valve. Richmond group. Wilmington, Illinois. Schuchert collection. See also plate IX, Fig. 7.

Fig. 7. *Strophomena planodorsata*. *A*, interior of pedicel valve; *B*, brachial valve. See also plate IX, Figs. 8 *A*, *B* for other views of 7 *B;* and Fig. 9 for other view of 7 *A*.

Fig. 8. *Strophomena planodorsata*. Interior of pedicel valve, enlarged 2.5 times. Richmond group. Iron Ridge, Wisconsin. University of Minnesota collection.

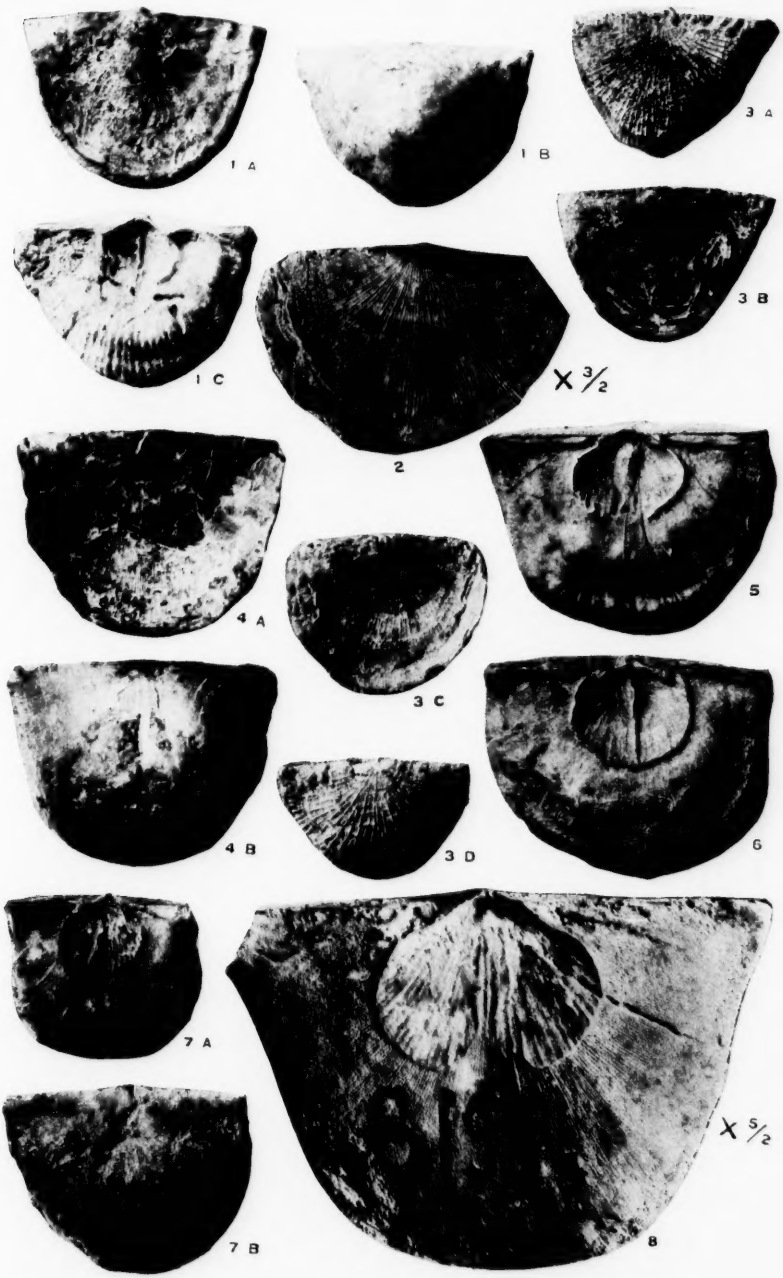

1 A
1 B
3 A
1 C
X 3/2
3 B
2
4 A
5
3 C
4 B
3 D
6
7 A
X 5/2
7 B
8

PLATE VIII

Fig. 1. *Strophomena planumbona.* *A*, *B*, pedicel valve, one view enlarged. *C*, *D*, brachial valves, one view enlarged. *E*, interior of pedicel valve. See also plate IX, Figs. 3 *A*, *B*. Type specimens, number 918–3, in the American Museum of Natural History, in New York City. Probably from Waynesville member, at Oxford, Ohio. Originals of Figs. 4 *a*, *b*, *c*, on plate 31 *B*, *Paleontology of New York*, vol. 1.

Fig. 2. *Strophomena subtenta.* *A*, *B*, brachial valves, one of the views enlarged. Type specimen, number 922–2, in the American Museum of Natural History, in New York City. Waynesville member of the Richmond; Oxford, Ohio. See also plate IX, Fig. 2.

Fig. 3. *Dalmanella emacerata.* *A*, *B*, brachial valve, one of the views enlarged. Type specimen, number 1339–2, in the American Museum of Natural History, in New York City. Original of Fig. 1, plate II, *Fifteenth Report of the New York State Museum.* Probably from Southgate member of Eden, at Cincinnati, Ohio.

Fig. 4. *Plectorthis fissicosta.* Pedicel valve, somewhat crushed. Type specimen, number 4490, in the American Museum of Natural History, in New York City. See also this Bulletin, vol. XIV, plate IV, Figs. 5 *A*, *B*, for views of the brachial valve. Fairmount member, at Cincinnati, Ohio.

Fig. 5. *Trematospira granulifera.* Brachial valve. Type specimen, number 1622, in Dyer collection, Harvard University. There is no hinge-area, the line in the figure having been added to suggest the amount of curvature of the beak of the pedicel valve. Said to have been found at Cincinnati, Ohio, but the origin is entirely unknown. Probably a Silurian or Devonian shell.

Fig. 6. *Hebertella subjugata.* Brachial valve. Type specimen, number 1342–1. Original of Fig. 1 *n*, on plate 32 *C*, *New York Paleontology*, vol. 1. Cincinnati, Ohio. Probably near Bellevue horizon.

Fig. 7. *Acidaspis, species?* Cephalon, rather imperfect. Number 9581, in the Faber collection, belonging to the Walker Museum, Chicago University. Lowry, Ohio. Horizon unknown. See also plate X, Fig. 6.

Fig. 8. *Austinella scovillei.* *A*, pedicel valve; number 105, James collection. *B*,*C*, interiors of pedicel valves; numbers 107, 106, James collection, Walker Museum, Chicago University. *A*, from Blanchester, Ohio. *B*, *C*, from Oregonia, Ohio, the type locality. Blanchester division of the Waynesville.

Fig. 9. *Austinella whitfieldi.* Interior of pedicel valve. Number 8114, in Gurley collection, in Walker Museum, Chicago University. Spring Valley, Minnesota. Richmond group.

Fig. 10. *Rafinesquina declivis.* Pedicel valve, enlarged almost twice the original diameter. See also this Bulletin, vol. XVI, plate V, Fig. 12 *C*. Boyd's Station, Kentucky. Type specimen, from series number 2392, in the James collection, in Walker Museum of Chicago University.

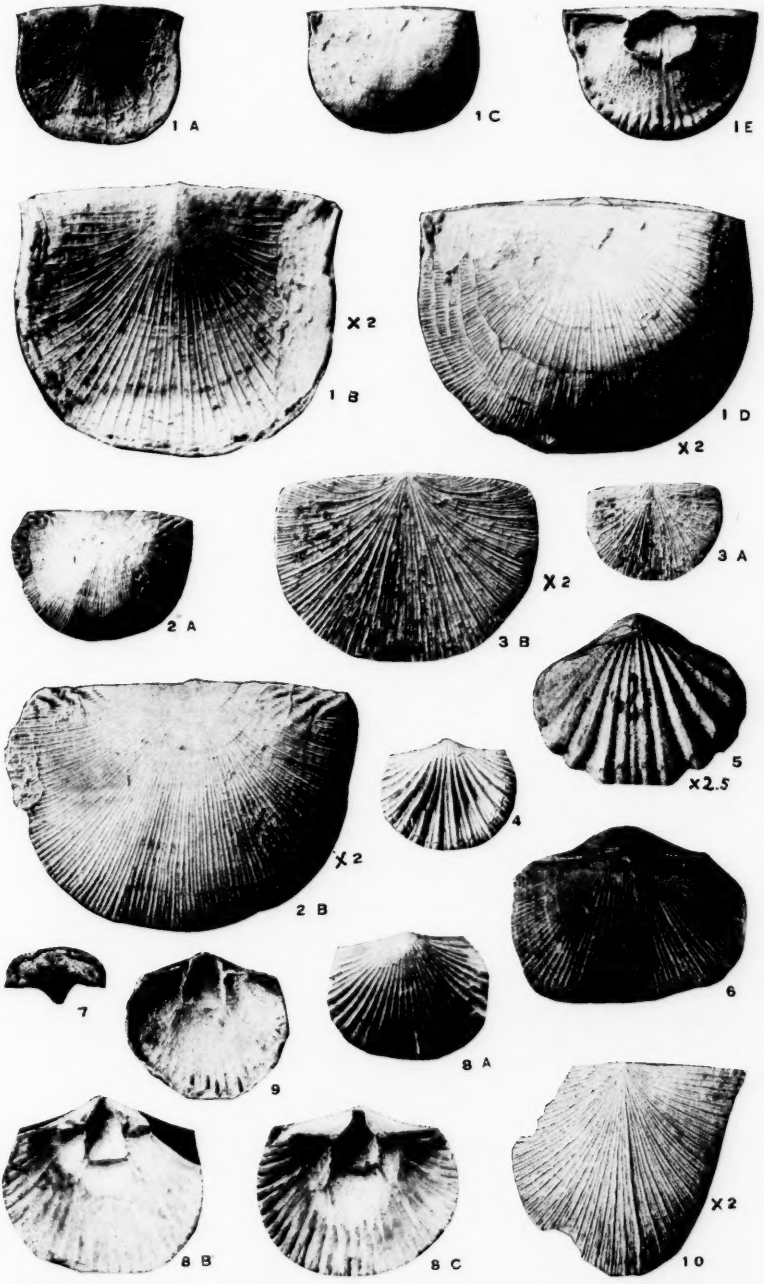

1 A
1 C
1 E
X 2
1 B
1 D
X 2
2 A
X 2
3 B
3 A
5
X 2.5
4
X 2
2 B
6
7
9
8 A
8 B
8 C
X 2
10

PLATE IX

Fig. 1. *Strophomena neglecta.* *A*, view along hinge area; *B*, brachial valve, with outlines restored; *C*, lateral view, with indication also of the curvature of the pedicel valve. Type specimen, number 2393, in the James collection, belonging to Walker Museum of Chicago University. See also plate V, Figs. 1 *A*, *B*. One mile west of Blanchester, Ohio. Blanchester division of the Waynesville.

Fig. 2. *Strophomena subtenta.* Curvature of brachial valve, viewed from the side. See also plate VIII, Figs. 2 *A*, *B*. Type specimen, number 922–2, in the American Museum of Natural History, in New York City; Oxford, Ohio. Waynesville member of the Richmond.

Fig. 3. *Strophomena planumbona.* *A*, view along the hinge area; *B*, lateral view, with indication also of the curvature of the pedicel valve. See also plate VIII, Figs. 1 *A*, *B*, *C*, *D*, *E*. Type specimen, number 918–3, in the American Museum of Natural History, in New York City, labelled as coming from Cincinnati, Ohio, but probably from Oxford, Ohio, in the Waynesville member.

Fig. 4. *Strophomena elongata.* *A*, view along the hinge area; *B*, lateral view, with indication also of the curvature of the pedicel valve. Type specimen, number 510, in the James collection, belonging to Walker Museum of Chicago University. See also plate IV, Fig. 1 *I*. Waynesville member. Possibly from Clarksville, Ohio.

Fig. 5. *Strophomena wisconsinensis.* *A*, view along hinge area; *B*, *C*, lateral views, with indications also of curvature of pedicel valves. *B* is a lateral view of *A*. See also plate VII, Figs. 1 *A*, *B*. Schuchert collection. Wilmington, Illinois. Richmond group.

Fig. 6. *Strophomena planodorsata.* *A*, lateral view, with indication also of curvature of pedicel valve; *B*, brachial valve. Type specimen, University of Minnesota collection. Richmond beds, Spring Valley, Minnesota. Copied from *Minnesota Paleontology*, vol. III, part 1, 1893. Plate XXXI, Figs. 8, 9.

Fig. 7. *Strophomena planodorsata.* Lateral view, showing curvature of pedicel valve. Type specimen, Schuchert collection. See also Plate VII, Fig. 6; and *Minnesota Geology*, vol. III, part 1, 1893, plate XXXI, Fig. 10. Wilmington, Illinois. Richmond group.

Fig. 8. *Strophomena planodorsata.* *A*, view along the hinge-area; *B*, lateral view, with indication of the curvature of the pedicel valve. Specimen much bent by crushing. Schuchert collection. Wilmington, Illinois. Richmond group. See also plate VII, Fig. 7 *B*.

Fig. 9. *Strophomena planodorsata.* Curvature of pedicel valve, seen from the side. Schuchert collection. Wilmington, Illinois. Richmond group. See also plate VII, Fig. 7 *A*.

Fig. 10. *Strophomena neglecta.* Curvature of interior of pedicel valve, seen from the side. Cited, but not figured by Schuchert in *Minnesota Geological Survey*, vol. III, 1893, p. 388. Savannah, Illinois. Schuchert collection. Richmond group. See also plate VII, Fig. 5.

Fig. 11. *Strophomena planodorsata.* Curvature of pedicel valve, seen from the side. Specimen, number 8191, University of Minnesota collection. Iron Ridge, Wisconsin. Richmond group. See also plate VII, Fig. 8.

Fig. 12. *Strophomena planodorsata.* Curvature of valves, antero-posteriorly. Nickles collection. Sterling, Illinois. Richmond group.

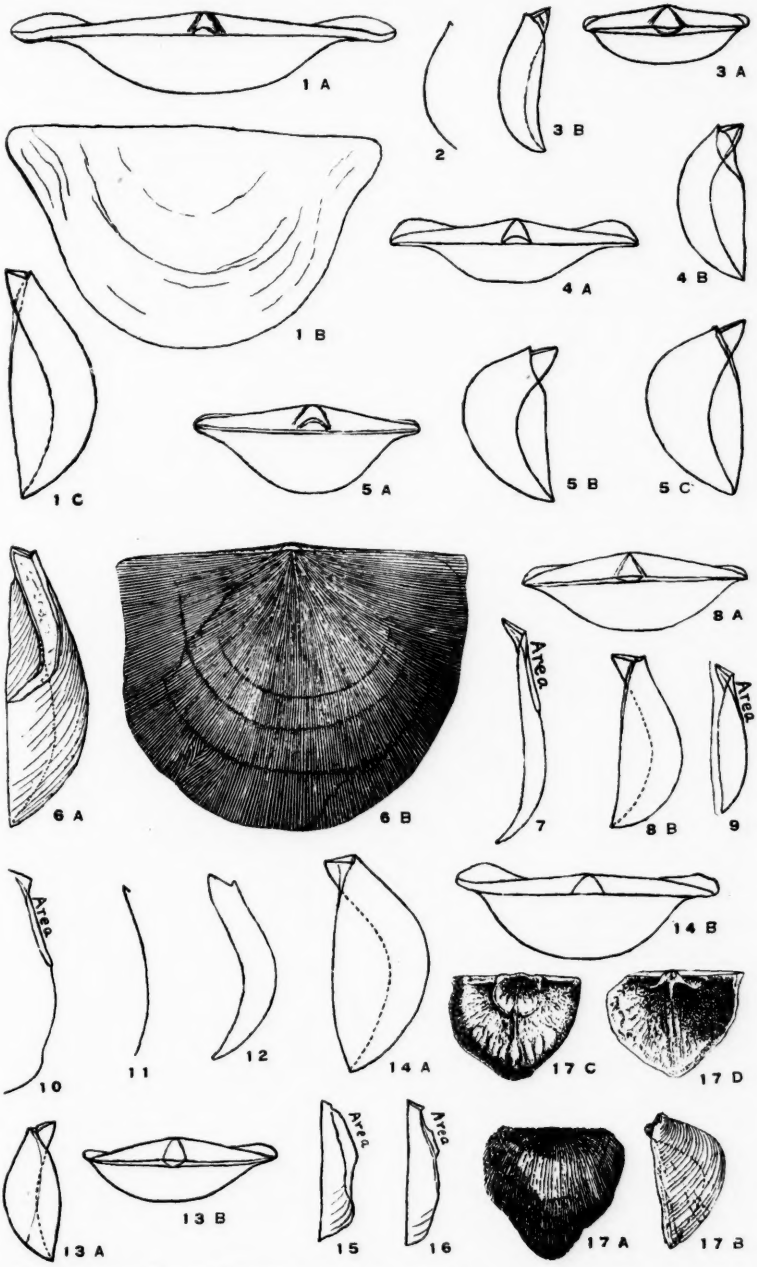

1 A
2
3 B
3 A
1 B
4 A
4 B
1 C
5 A
5 B
5 C
6 A
6 B
8 A
Area
7
8 B
Area
9
Area
10
11
12
14 A
14 B
17 C
17 D
13 A
13 B
Area
15
Area
16
17 A
17 B

PLATE IX—Continued

Fig. 13. *Strophomena acuta*. *A*, lateral view, with indication of curvature of pedicel valve. Schuchert collection. Spring Valley, Minnesota. Richmond group. See also plate VII, Fig. 3 *A*.

Fig. 14. *Strophomena planodorsata*. *A*, lateral view, with indication of the curvature of the pedicel valve; *B*, view along hinge area. Mannie clay, forming upper part of Richmond group, a quarter of a mile northeast of Fly, beyond the home of R. S. Elam. See also plate VII, Figs. 4 *A*, *B*.

Fig. 15. *Strophomena nutans*. Lateral view of pedicel valve, showing contour of interior. Blanchester division of Waynesville. Oregonia, Ohio. See also plate X, Fig. 2 *A*.

Fig. 16. *Strophomena nutans*. Lateral view of pedicel valve, showing contour of interior. Clarksville, Ohio. Blanchester division of the Waynesville. See also plate X, Fig. 3 *B*. The convexity of the interior outline of the valve is slightly exaggerated.

Fig. 17. *Strophomena fluctuosa-occidentalis*. *A*, brachial valve; *B*, lateral view, with indication of curvature of pedicel valve; *C*, interior of pedicel valve; *D*, interior of brachial valve. Richmond group, at Spring Valley, Minnesota. Copied from *Minnesota Geology*, vol. III, plate XXXI, Figs. 14, 15, 16, 17.

PLATE X

Fig. 1. *Strophomena vetusta-precursor*. *A*, Brachial valve. *B*, Pedicel valve. *C*, Interior of pedicel valve. Two miles southwest of Clarksville, Ohio, on Penquite Run, south of the pike to Middleboro. Blanchester division of the Waynesville.

Fig. 2. *Strophomena nutans*. Three interiors of pedicel valves. *A*, from Oregonia, Ohio; see also plate IX, Fig. 15. *B*, *C*, from the same locality. Blanchester division of the Waynesville.

Fig. 3. *Strophomena nutans*. Not the typical form, but approaching *Strophomena concordensis* in general appearance. *A*, *B*, *C*, *D*, interiors of the pedicel valve. Stony Hollow, northwest of Clarksville, Ohio. Blanchester division of the Waynesville.

Fig. 4. *Strophomena higginsportensis*. Interior of pedicel valve. Same specimen as Plate II, Fig. 3 *B*. Stony Point, east of Higginsport, Kentucky. Horizon unknown, but probably low in the Eden.

Fig. 5. *Orthoceras tyronensis* covered by *Dermatostroma tyronensis*. *A*, High Bridge, Kentucky; *B*, nearly 2 miles northwest of Bryantsville, Kentucky, where the road turns northward and descends into a ravine. Tyrone member.

Fig. 6. *Acidaspis, species?* Cephalon, imperfectly preserved; magnified 1.8 diameters. Same specimen as that on Plate VIII, Fig. 7. Number 9581, Faber collection, in Walker Museum, Chicago University. Lowry, Ohio. Exact horizon unknown.

Fig. 7. *Plectambonites rugosa-clarksvillensis*. *A*, *B*, *C*, three interiors of brachial valves; *D*, interior of pedicel valve. *A*, southeast of Oxford, Ohio; *B*, Concord, Kentucky; *C*, exact locality unknown; *D*, east of Weisburg, Indiana. *A*, Clarksville division of the Waynesville; *C*, probably the same horizon; *B*, *D*, lower part of Liberty member.

Fig. 8. *Lingula procteri-versaillesensis*. Brachial valves. *A*, older individual. *B*, younger form. Versailles, Kentucky, along the railroad to Frankfort. Upper part of Paris bed.

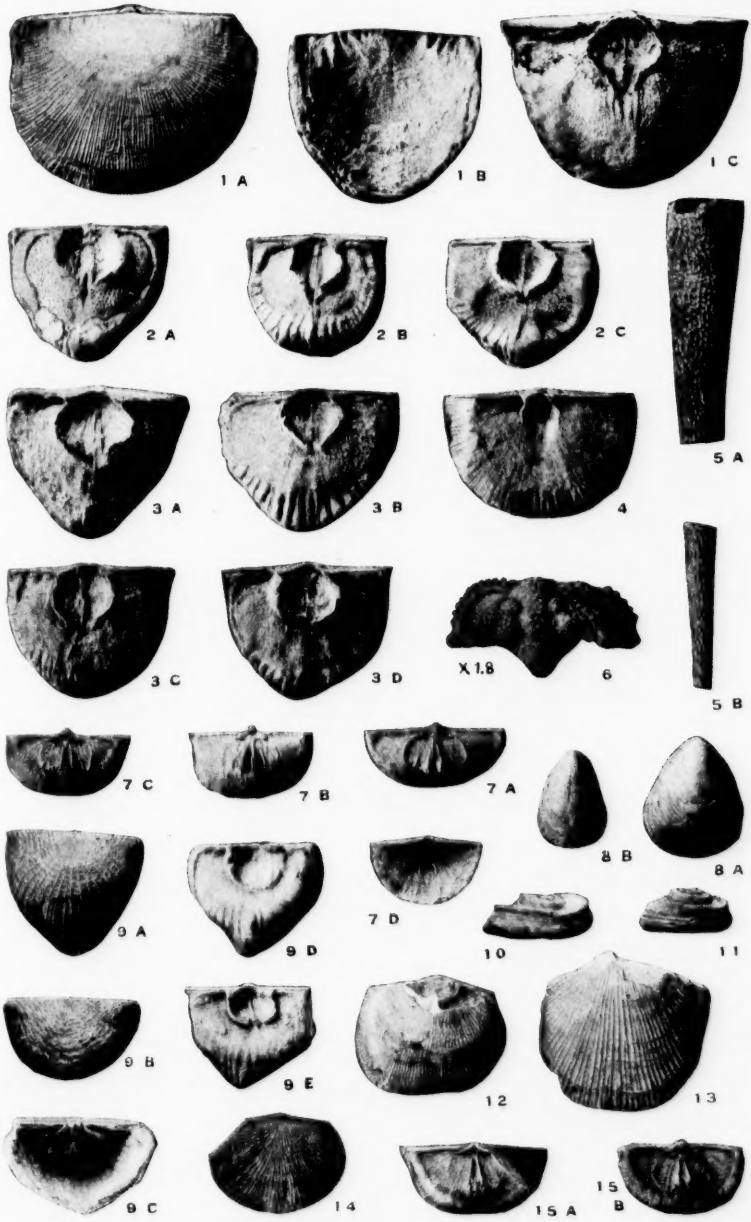

1 A
1 B
1 C
2 A
2 B
2 C
5 A
3 A
3 B
4
3 C
3 D
X 1.8
6
5 B
7 C
7 B
7 A
8 B
8 A
9 A
9 D
7 D
10
11
9 B
9 E
12
13
9 C
14
15 A
15 B

PLATE X—Continued

Fig. 9. *Strophomena fluctuosa-occidentalis.* *A*, *B*, brachial valves, with the concentric wrinkles not well brought out by photography. *C*, interior of brachial valve, the valve strongly tilted so as to show the muscular area. *D*, *E*, interiors of the pedicel valve. F. W. Sardeson collection. Spring Valley, Minnesota. Richmond formation.

Fig. 10. *Helicotoma* sp. Lateral view of the specimen figured on Plate XI, Fig. 4. West of Elkhorn Falls, 3 miles southeast of Richmond, Indiana. Elkhorn member.

Fig. 11. *Helicotoma brocki.* Lateral view of the specimen figured on Plate XI, Fig. 3. Kagawong, Manitoulin Island. Richmond formation.

Fig. 12. *Clitambonites multistriata.* Partially exfoliated pedicel valve. Half a mile north of the railroad station at Danville, Kentucky. Perryville bed.

Fig. 13. *Clitambonites diversus.* Pedicel valve. Ellis Bay. Anticosti.

Fig. 14. *Strophomena millionensis.* Brachial valve. An eighth of a mile west of the tunnel west of Million, Kentucky. Lower part of Eden.

Fig. 15. *Plectambonites curdsvillensis.* Brachial valves, interior views. Southwest of Crow Distillery, Glenn Creek, Woodford county, Kentucky. Curdsville bed.

PLATE XI

Fig. 1. *Strophomena concordensis-huronensis.* *A*, *B*, *C*, *D*, *E*, interiors of pedicel valves; *F*, *G*, pedicel valves with wrinkles along the hinge line; *H*, *J*, brachial valves with wrinkles along the hinge-line; *K*, interior of brachial valve. Clay Cliffs, 3 miles north of Wekwemikongsing, east end of Manitoulin Island. Richmond group.

Fig. 2. *Strophomena sulcata.* *A*, brachial valve. *B*, pedicel valve. Kagawong, Manitoulin Island. Richmond group.

Fig. 3. *Helicotoma brocki.* Kagawong, Manitoulin Island. Richmond group. See also Plate X, Fig. 11.

Fig. 4. *Helicotoma* sp. West of Elkhorn Falls, 3 miles southeast of Richmond, Indiana. Elkhorn member of the Richmond. See also Plate X, Fig. 10.

Fig. 5. *Orthorhynchula linneyi.* Brachial valve, with beak of pedicel valve showing above it. Four miles north of Versailles, Kentucky. Perryville bed.

Fig. 6. *Strophomena planumbona-gerontica.* Lateral view, showing convexity and obesity of brachial valve. Hillside west of Gore Bay, Manitoulin Island. Richmond group.

Fig. 7. *Strophomena incurvata.* Pedicel valve, interior view. High Bridge, Kentucky. Tyrone member of High Bridge limestone.

Fig. 8. *Strophomena nutans.* Fragment of pedicel valve, interior view. Clay Cliffs, 3 miles north of Wekwemikongsing, Manitoulin Island. Richmond formation.

Fig. 9. *Strophomena incurvata.* *A*, brachial valve; *B*, pedicel valve, interior view; *C*, brachial valve, interior view. *A*, LaCloche Island; *B*, *C*, Goat Island; both northeast of Manitoulin Island. Black River formation.

Fig. 10. *Strophomena neglecta.* Pedicel valve, interior view. Kagawong, Manitoulin Island. Richmond group.

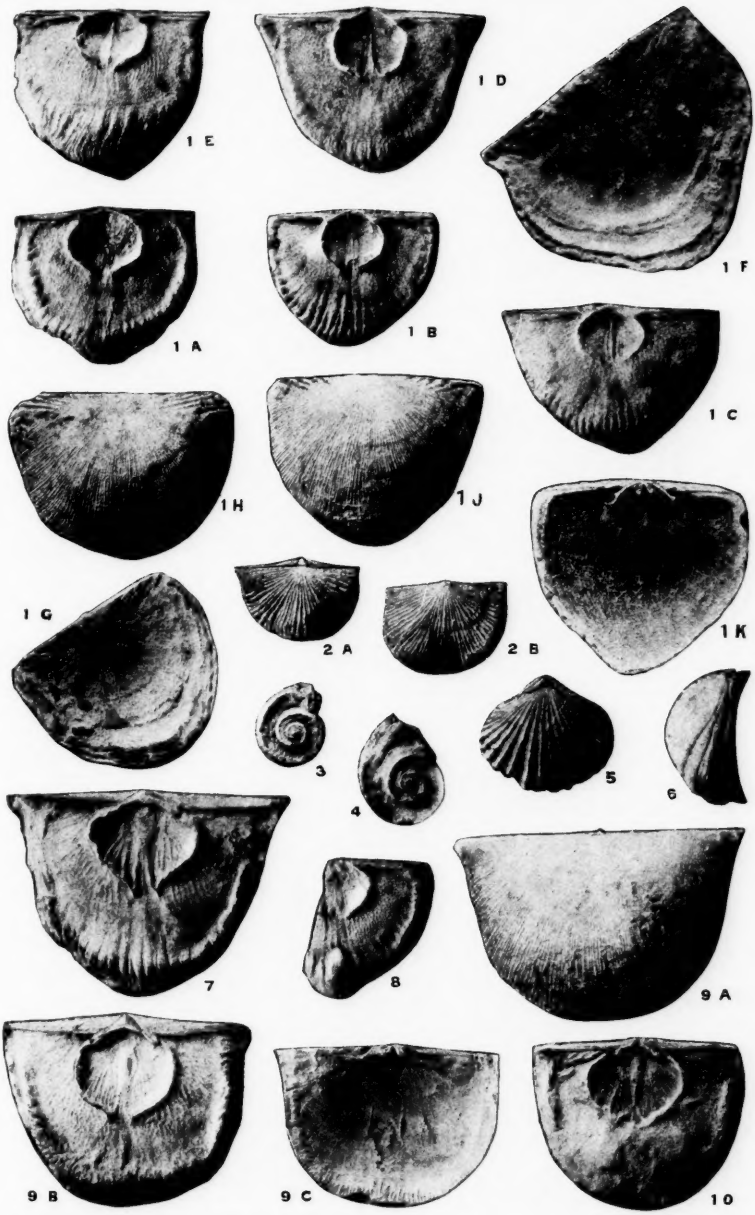
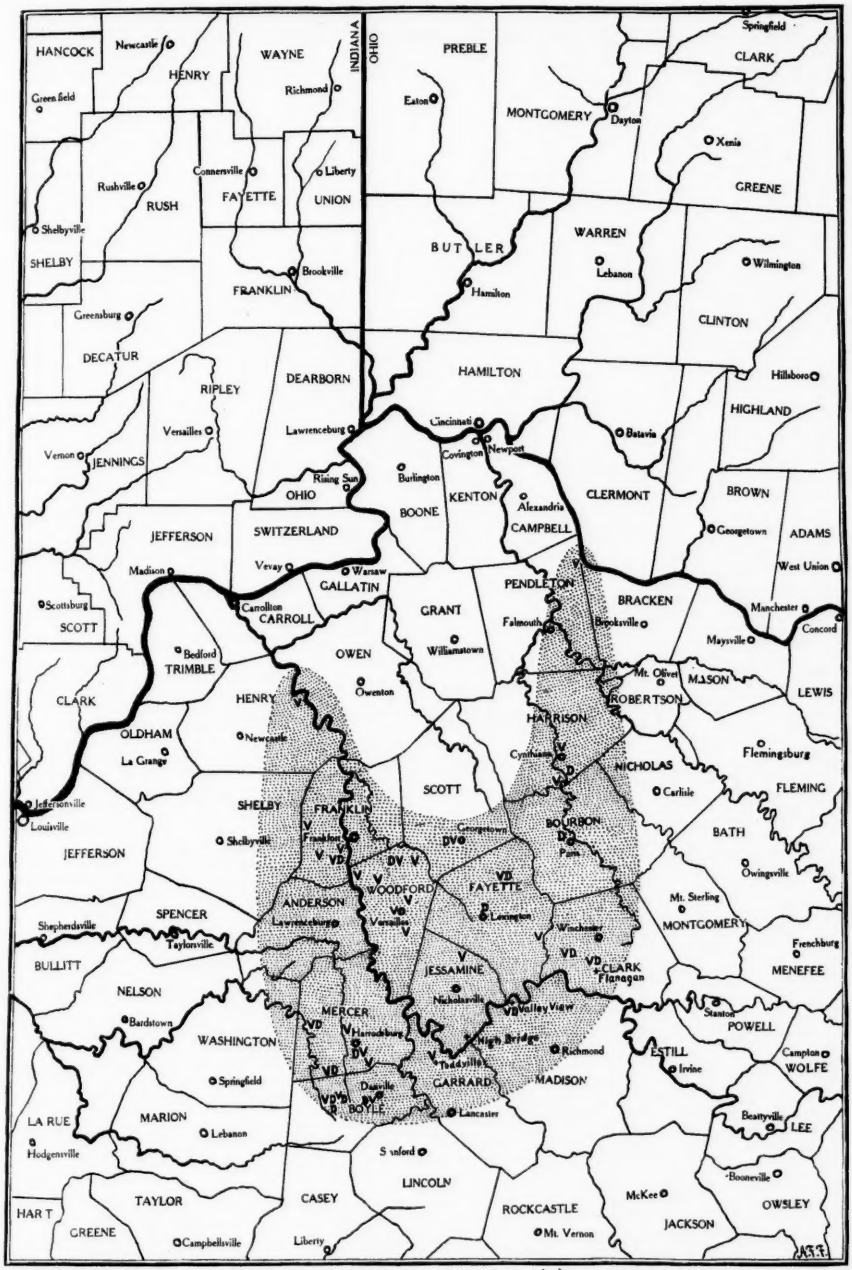

1 E
1 D
1 F
1 A
1 B
1 C
1 H
1 J
1 G
2 A
2 B
1 K
3
4
5
6
7
8
9 A
9 B
9 C
10

PLATE XII

Charts illustrating the distribution of various species of fossils.

The following charts indicate the localities at which various species of fossils actually have been found. The species are designated by the letters used. The number of localities indicated depends not only on the former distribution of the species in question, but also on the extent of the areas within which at present the containing strata are exposed and on the amount of field work done within these areas. The delimitation of various areas by means of dots and other devices is intended merely to assist the eye by indicating on which parts of the chart it is worth while to look for the letters indicating the presence of fossil localities. Since, evidently, the same strata must extend for many miles under cover, and since unquestionably their ranges frequently extended across areas from which the containing strata have subsequently been removed by erosion, these charts in no sense indicate the entire former distribution of the fossils under consideration, but only that part of this area at present accessible and within which the search for the species in question has been found successful. Moreover, since the writer has not had the opportunity of visiting more than a small part of the exposures easily accessible, sometimes only one or two localities in an entire county, it is evident that future search will much extend our knowledge of the geographical distribution of these species.

Plate XII indicates the distribution not only of *Strophomena vicina*, but also of *Dinorthis ulrichi*, which at numerous localities is associated with the former species, especially at the Cornishville horizon, but also occasionally near the base of the Paris bed.



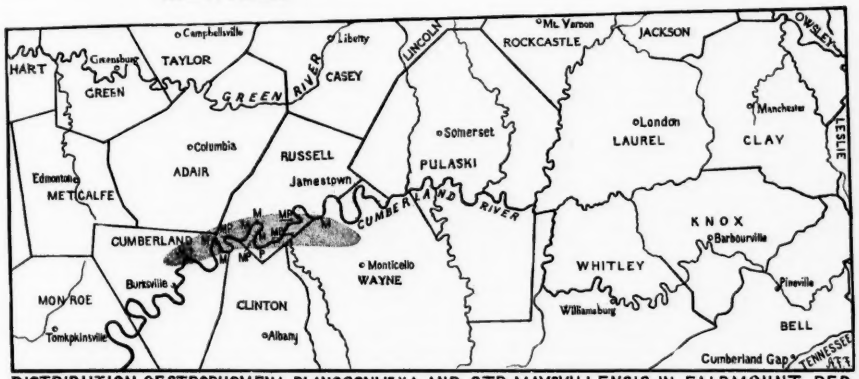
DISTRIBUTION OF STROPHOMENA VICINA (V) AND DINORTHIS ULRICHI (D) IN UPPER PART OF LEXINGTON LIMESTONE

PLATE XIII

The dotted area indicates the distribution of the localities at which *Strophomena hallie* has been found. The triangle within the limits of Madison county, Kentucky, indicates the only known locality for *Strophomena millionensis*. The limited area along the Ohio River, crossed by broken lines, includes the two localities at which *Strophomena higginsportensis* is known. *Strophomena hallie* and *Strophomena millionensis* occur in the Eden. The horizon of *Strophomena higginsportensis* is either the basal Eden or the underlying part of the Cynthiana formation.

DISTRIBUTION OF STROPHOMENA HALLIE(H), STR. MILLIONENSIS(M), AND STR. HIGGINSPORTENSIS IN THE EDEN AND CYNTHIANA BEDS.

DISTRIBUTION OF STROPHOMENA PLANOCONVEXA, STR. MAYSVILLENSIS, AND STR. SINUATA IN FAIRMOUNT AND MOUNT HOPE BEDS.



DISTRIBUTION OF STROPHOMENA PLANOCONVEXA AND STR. MAYSVILLENSIS IN FAIRMOUNT BED.

BULLETIN OF THE DENISON UNIVERSITY, VOL. XVII, ARTICLE 2

PLATE XIV

The dotted line includes the area within which *Strophomena maysvillensis* and *Strophomena planoconvexa* occur. The species are differentiated by the letters. The area covered by broken lines indicates the distribution of *Strophomena sinuata*, very imperfectly known at present.

PLATE XV

This plate is a southward extension of the chart included on Plate XIV, and gives the distribution of *Strophomena maysvillensis* and *Strophomena planoconvexa* along the Cumberland River, in southern Kentucky.

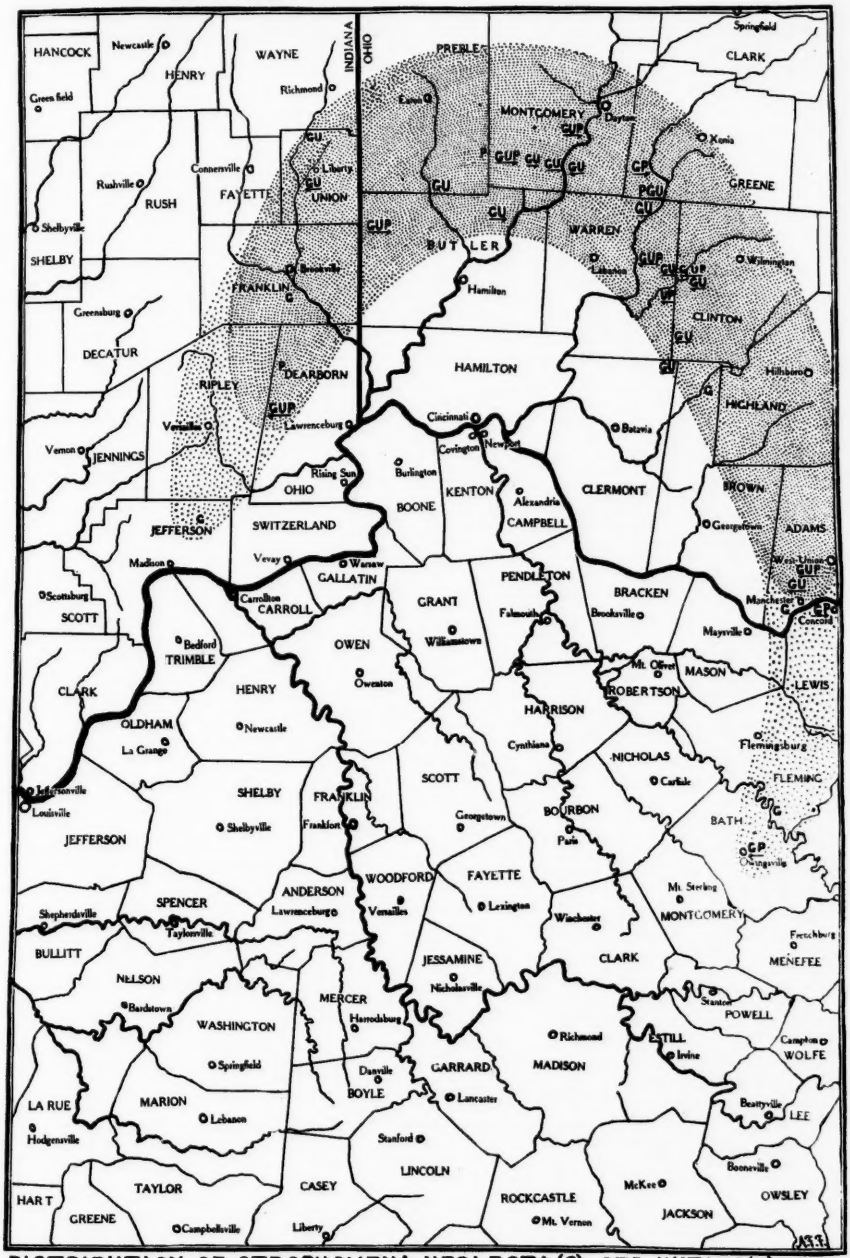
PLATE XVI

The geographical distribution of *Strophomena concordensis* at the top of the Arnheim member of the Richmond.

DISTRIBUTION OF STROPHOMENA CONCORDENSIS AT TOP OF ARNHEIM BED.

PLATE XVII

The dotted area indicates the region in which *Strophomena neglecta* and *Strophomena vetusta-precursor* are found. The more densely dotted part of this area gives the present known distribution of *Strophomena nutans*, which seems to have a more limited range.

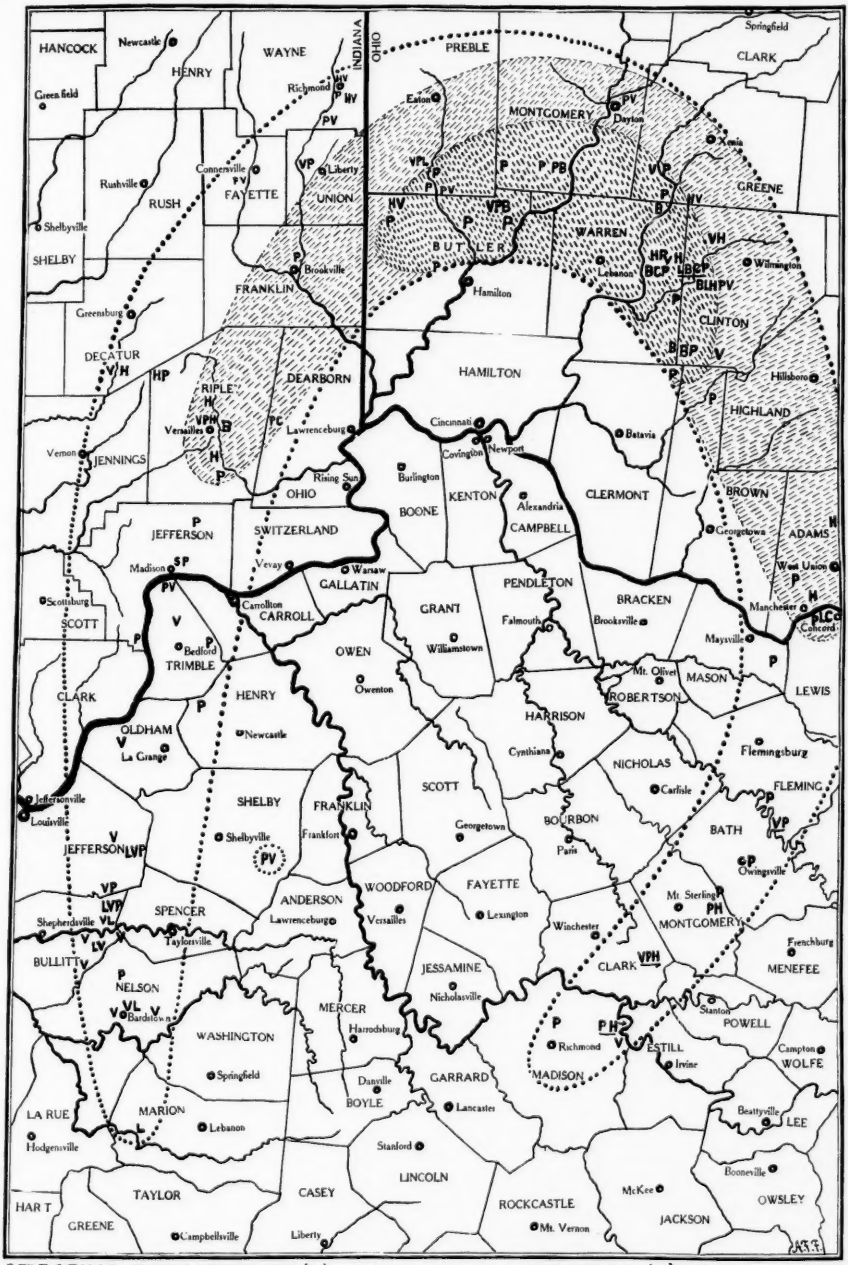


DISTRIBUTION OF STROPHOMENA NEGLECTA (G), STR. NUTANS (U), AND STR. VETUSTA-PRECURSOR (P) IN BLANCHESTER OR UPPER WAYNESVILLE.

PLATE XVIII

The known geographical distribution of *Strophomena sulcata* is indicated by the area included within the dotted line. The much more limited area covered by broken lines indicates the range of this species during Waynesville times. The lines directed diagonally upward and toward the left designate the area within which *Strophomena sulcata* has been found at the lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville. The extension of this area by diagonal lines directed upward and toward the right indicates how much greater is the known geographical range of this species during the Clarksville division of the Waynesville. The remainder of the space included within the dotted line indicates how much farther the known range of this species extends in the Liberty and Whitewater beds. In place of using a single letter to designate the locality at which *Strophomena sulcata* is known, the letter is varied so as to designate the horizon instead, in accordance with the scheme indicated at the base of the plate.

The distribution of *Strophomena vetusta* and of the various varieties of *Strophomena planumbona* is indicated by the letters *V* and *P* respectively.



STROPHOMENA VETUSTA(V) AND STR. PLANUMBONA (P) IN RICHMOND
STR. SULCATA IN WHITEWATER, SALUDA, LIBERTY, BLANCHESTER, CLARKSVILLE
AT BASE OF BLANCHESTER ▨, ALSO IN CLARKSVILLE ▨, IN HIGHER ZONES ⋰⋱

POPULATION CENTERS AND DENSITY OF POPULATION

FRANK CARNEY

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GENERAL PRINCIPLES

It is a common observation that a very large percentage of mankind live in the lowlands, especially the lowlands that are not far vertically from sea-level. As population has become more dense in various parts of the world, man has learned to live under all kinds of topographic conditions, but primitive man was not a mountaineer. When people move into a new

country they are influenced by certain relationships of topography in locating their homes and their villages. Some general principles may be cited as representing these tendencies.

In the first place, all the great cities of the world today are either on the sea, on estuaries leading tidal-waters some distance into the land, or on the flood plains of rivers. In areas that are distant from the sea, the river-valleys usually determine where the early abodes are to be. Travel across continents is easier along the trenches that have been cut by the rivers; if a different course is required, the divides are chosen. A map of the Indian trails that the white men discovered in Ohio shows that the Indians followed the divides quite as often as the valleys; they wanted a lookout in their travels. This principle of river-valleys directing the early movements of men in Ohio may be illustrated by a study of the early cities of this state.

Again, we very often find man planting his abodes and developing his industry in areas marked by the confluence of river valleys, because, where streams unite, the flood plain is always broader, and the soil of the bottom land is richer. The early farms, therefore, can be larger and more productive. The most expensive farm land in Licking county is found in the very mature valley of what was probably the largest river that ever crossed central Ohio, a valley long out of use, except as portions of the present rivers follow segments of its course.

FACTORS IN THE LOCATION AND GROWTH OF POPULATION CENTERS

Early settlements in Ohio. During the early settlement of Ohio, the centers of population were very few and widely scattered. Invariably they were in agricultural regions. The pioneers of Ohio were farmers. These early farm locations, so far as was allowable under the conditions of the grants acquired by the land companies, were contiguous to routes that led the pioneers into the state. Of these routes, the Ohio river was the one that was most dependable all the year round; therefore, the location of the earliest farms in Ohio was often decided by the point at which the pioneer reached the Ohio river. If he came directly from the east, approaching the river from the present site of Pittsburg or of Wheeling, he was probably attracted by some of

the tributary valleys in that part of the state. If he came from the south by the old Wilderness road, from the Coast colonies, he probably crossed the Ohio at Maysville or farther west, and prospected northward through the valleys in that locality. The earliest party of all was attracted by the fertile lowlands where the Muskingum flows into the Ohio.

Almost contemporaneous with the founding of this agricultural colony, Marietta, was the planting of a colony at Columbia near Cincinnati, located conveniently on the Ohio, and adjacent to two broad fertile areas extending toward the north, the valleys of the Great Miami and the Little Miami rivers. The Scioto also attracted early settlers, but disastrous experiences with the Indians checked the founding of permanent settlements near its mouth, as well as at some other points along the Ohio.

Early importance of Cincinnati. The richest agricultural areas of the state, during the early decades of its settlement, were found in the southwest. The most rapid growth made by any town in the state was naturally associated with this center of agriculture. Accordingly, Cincinnati grew faster than any other of Ohio's pioneer villages. The reactions that always follow prosperous farming tended to make Cincinnati the metropolis of the state, and so long as Ohio was known to the outside world as purely an agricultural commonwealth, Cincinnati continued to be its leading city; when the dependence was placed later on other sources of wealth also, Cincinnati lost its position as the metropolis, giving place to Cleveland.

Zane's Trace. The condition which accounts for the settlement of agricultural areas extending north from the Ohio valley did not universally prevail during the pioneer days, because of another factor which came into operation when the Federal Congress decided to make a post-road across the state, from the vicinity of Wheeling to a point on the Ohio opposite Maysville, Kentucky. Zane's Trace started from opposite the present site of Wheeling, bore directly west to the vicinity of Cambridge, thence a little south to Zanesville, west again to Lancaster, thence south, crossing the Scioto at Chillicothe, and continuing southwestward to Maysville. This road led some pioneers to ignore the valleys, and to take up homesteads along its course. Accordingly, agricultural villages developed at an early date at the places named above. One other factor in the location of these villages is found

in the bargain which Engineer Zane made with Congress. He agreed to survey this line, on condition that he should receive one square mile of territory at each of the points where his line crossed the three rivers, the Muskingum, the Hocking, and the Scioto. Wilderness land was not then at a premium in the estimation of Congress, so, with the settling of a few other conditions, the bargain was completed, and Mr. Zane located the road. Immediately afterwards postmen commenced to ride through, and the first mail to cross the state went over this highway. The first town Zane located, he named after himself, Zanesville; the next was named Lancaster, and the third Chillicothe. It is interesting to study the influence of this trace (the Maysville Road, as it is sometimes called) on population in later decades; its effect is indicated in the decennial population maps.

Readjustments due to the canals. Later, centers of population developed for other reasons. The markets formerly had been reached by ox teams or horses, and, naturally, were limited. When canals commenced to operate, new places appeared on the map. The principles above stated, however, were still in operation, because the canals followed valleys, wherever possible. Villages were already scattered through the valleys. The influence of the canals was observed, however, in giving certain towns an advantage over certain other towns; for example, if, in a valley fifty miles long, there were three places of about equal importance, all reached by highways, and the business carried on by trucking, the particular town best situated, both in reference to the farm regions and the canal, soon had a handicap on the other two places.

The Ohio canal follows the Scioto from Portsmouth to Lockbourne; then it turns eastward into the old Newark river valley, which it follows to Hanover; from this point it continues along the Licking river to Toboso, thence it enters the Muskingum valley which it follows northward towards Akron, north of which its course is along the Cuyahoga valley to Cleveland. The Miami and Erie canal extends from Toledo, southward through Dayton, to Cincinnati. A few laterals from these canals reach territory east and west. But the day of the canal was short, because steam traffic on land was instituted not long after the canals were built, and railroads took the place of canals. The canal period, however, was long enough to change many ordinary towns into important cities.

Railways and population centers. Most of the early railroads of Ohio were responses to industrial needs outside of the state; the canals were entirely of local origin. Because of this fact, the railways took courses which were not always of the greatest convenience to Ohio. In the main, they were built to connect places on either side of Ohio, and they crossed the state more often at the convenience of the terminal points. Nevertheless, certain centers of population came into existence purely because of the railroads. The northern part of the state, the southern part, and later the central part, were crossed by railways. Somewhat later the interests of people in Ohio led to the construction of north-south railways, which proved a benefit to many towns that hitherto had been left aside, and brought into existence several new towns.

A railroad, topographically located, in passing through Licking county, must cross the immediate environs of Newark. The railroad entrances to Licking county, that is, the valleys, lead to Newark; therefore, Newark was destined by nature to be the most densely settled section of that county. At the confluences of valleys modern industry enlarges on the advantages that appealed to the pioneer; later, railroads converge at such points. The shipping facilities of such a location tend to make the population more dense. Newark has natural advantages which few other places in central Ohio possess.

Influence of political convenience. Another factor in creating centers of population is political convenience. To this factor Columbus owes much of its initial development. It is near the center of the state, is accessible physiographically, and therefore the correct location for the legal business of the commonwealth. But in the earlier decades, very few of the factors discussed above were operative in the development of a city at Columbus. Two other places were tried as the capital of Ohio, but, as settlements spread over the state, the location of the capital was changed because these places were not central.

In several counties of Ohio one wonders now at the location of the county-seats; they may be geographically central in relation to the highways of the county, and were probably convenient when the population was evenly distributed and travel was by horseback or in carriages. But recent decades have witnessed a marked redistribution of the population, and the construction of modern

transportation lines which make the county-seats relatively inaccessible. Some of the counties of the state are in a ridiculous condition in this respect. All the county business, the holding of courts and the paying of taxes, is done at a place which is inconveniently located so far as the great majority of the citizens of the county is concerned. The county-seat of Licking county is still logically placed; all parts of the county trend physiographically toward Newark, where nearly half of the citizens of the county live.

Arbitrary industrial purposes. Another factor in the development of centers of population is sometimes very important, but becomes operative later in the life of a commonwealth. When a more mature industrial stage is reached, congested centers may appear in spite of the location, and contrary to some of the principles already discussed. Barberton, in Summit county, in the last decade made a remarkable growth in consequence of a match manufactory. Other important population centers, illustrating the operation of this factor, are Depew, N. Y., and Gary, Illinois.

But while we find certain centers of population springing into existence in spite of the basal principles already stated, owing their origin entirely to an arbitrary industrial purpose, nevertheless, in the course of time such centers must stand the test of the basal principles.

The original highways, before canals or railroads came into existence, converged at valley junctions. In some instances, the enlarged industry of recent decades has built on the basis of population centers already in existence. Cases similar to Barberton, or Gary, Ill., are very rare, and are interesting in showing the stupenduous power of mature industry.

TYPICAL EARLY CENTERS

Cincinnati, the first manufacturing town. Reference has already been made to Cincinnati's early growth. The fertile farmlands back of Cincinnati made it a large city in the early days of the last century. In the Miami valleys abundant crops were grown, some of which were marketed down stream by boats. The farmers had money to purchase much-needed articles, but these were obtained with difficulty from the manufacturing centers of the Atlantic seaboard. The chief obstacle was the exorbitant price that was asked for goods which had to be carted across the Appa-

lachian mountains. Cincinnati, therefore, started early to manufacture the things demanded by the nearby farming industries. Thus the first manufacturing town west of the Alleghenys was created by home demands. More money came into circulation, and banking was shortly an important and necessary business. As a result of this early prosperity, a great amount of capital was available, and Cincinnati became an important center of long-distance business, in the first place by boat even to Europe, and later, when the canals were constructed, by the transportation of goods from the Ohio river to Lake Erie, via the Erie canal, to New York. Several factors gave Cincinnati an advantage over any other town of the state; the concentration of trans-Appalachian exchange through Cincinnati's banks for many decades is a matter to which we may not assign proper value. Banking business is generally conservative. Several old established banks of the Atlantic cities, which commenced early last century to place all their western exchange through Cincinnati, still continue to do so.

Chillicothe. In the early days of last century, one traveling overland from Cincinnati toward the sea, would probably have passed through Chillicothe. For several decades, Chillicothe was a very important place; agriculturally, it is more advantageously located than is Portsmouth, which is at the mouth of the Scioto river. The area of the lowland farming section increases from Portsmouth northward. The Scioto is a very recent stream geologically; for a long time antedating the glacial period, a great river, which had its origin in the Appalachian slopes of Kentucky and West Virginia, flowed northward, following in part of its course, what is now the Scioto valley, but in a reverse direction. Chillicothe lies in a mature part of that old valley, and the area of the good farmland decreases southward from Chillicothe.

Cambridge. Cambridge also, during the early decades, was a center of importance. It was located on Zane's Trace, the eastern part of which later became the National Road. During the stage-coach days, Cambridge was the first town of consequence to be met west of the Ohio. But when railways took the place of the slower methods of travel, Cambridge was not so favored; the through lines did not pass its way, and the advantages it had enjoyed in consequence of the former stage-coach traffic and the fairly good agricultural surroundings became relatively less and less important.

Cleveland. Among these early population centers mention should be made of Cleveland, though for a long time it was a place of little importance. It was at the mouth of a river, but the harbor was not inviting, and there was no distant trade that followed Lake Erie, no railways from the eastern end of the lake to transport goods to the big markets; it was not until the Erie canal was opened that Cleveland commenced to be much more than a village; in the decade, 1830 to 1840, its population increased 464.2 per cent. During the pre-canal period both Brooklyn and Newburg were larger towns, because they were situated on higher ground and were more approachable from the farming areas, south and west. Brooklyn particularly had a handicap on Cleveland in the river channel, which stood in the way of traffic from the west. Farmers on the east side of the Cuyahoga and a few miles south of the lake, in order to reach Cleveland, had to use a difficult roadway involving many long grades; it was much more convenient for them to transact their business on the top of the escarpment at Newburg.

With the impetus given lake trade by the facilities for freighting through the Erie canal, Cleveland at once became a transportation point both for goods from the east and for goods that the people in that locality wished to market, and this trade was further increased when the Ohio canal was opened. With this exchange, Cleveland commenced to grow, but Cleveland's growth, unlike that of these other places above noted, was not largely dependent on agriculture. Secondary industries, because of the shipping, became important early in the history of this town; chief among these was boat building. Goods for Buffalo and the other lake ports were shipped by boats, and the Cleveland shipyards foreshadowed the commerical future of the city.

With the opening up of the Ohio canal, a new source of industrial energy was attracted to Cleveland. South of Cleveland, it had long been known, the hills bore coal-beds, but there was no demand for coal in the little village at the mouth of the Cuyahoga, so there was no incentive to mine coal. When the Ohio canal reached Cleveland, insuring low freight rates, these coal mines at once were opened, and the cheap fuel brought to Cleveland led to the establishment of still other industries. Cleveland is not an agricultural city in its origin; it is a manufacturing city, always has been, and will probably never be anything else.

Northwestern Ohio. It was not till toward the middle of the last century that travel in the northwest part of the state became convenient. That was the last section to be settled, and, as a result, the centers of population elsewhere in the state had a decided start. Later, railways connecting the Atlantic seaboard and the west added to the prestige of Toledo. The extreme northwest corner of Ohio profited also by nearness to Michigan, the southern part of which was settled much earlier. These communities wished an outlet to the east, hence a railroad was built in 1836 from southern Michigan across the corner of Ohio to Lake Erie, and connected there with boat-freighting. For a long time Toledo made a very meagre growth, and Sandusky also grew slowly. The Miami and Erie canal made Toledo a shipping point for goods to and from the East, via Lake Erie.

The agricultural possibilities of the northwestern part of the state were early recognized, but the area was not attractive to the pioneer; it was famous chiefly for its marshes. To turn these marshes into farmland required great labor; the pioneer had not the conveniences for constructing effective ditches. For this reason the northwest part of the state did not attract the early farmers.

DENSITY OF POPULATION

What is over-population. All may not agree on an answer to the question, when is an area over-populated? Some hold that an area is over-populated when the inhabitants cannot get a normal amount of food; others, that over-population is reached long before that condition of stringency arises. We are under biological contract with destiny to make constant progress as a race; keeping the species in existence, is no guarantee of advancement. From this viewpoint, an area may be over-populated before its inhabitants cease to be properly nourished. When the struggle for physical existence monopolizes the attention of any part of the human race, that part cannot rise to higher planes. So long as man is becoming progressively more and more the master of his environment, the race is advancing. Poorly-fed peoples have never performed great engineering feats. Codes of ethics have never been evolved by starved nations. It takes prolificness in all ways to insure moral as well as material progress.

Types of over-population. There are two kinds of over-population, local and general. Some particular parts of a state may have too many citizens, whereas the state itself has room for many more. Particular states of a nation may be densely populated, and at the same time the general density of the whole nation fall far short of over-population. History records very few cases of general over-population, but there are numerous records of too great local density.

In the population records of some of the older countries, there are cycles which sometimes are so emphasized that we may misjudge the population capacity of the area under normal conditions. The occasional occurrence of famines in these countries, in which the mortality is very high, does not signify over-population; it means primitiveness in sanitation, and an ignorance of the cause of disease, a condition that is now approximated in the United States in particular diseases, such as typhoid fever, tuberculosis, and syphilis. In North America there are no records of famines or plagues since the white men commenced in earnest to take hold of the country; stories of famines among the Indians are current in legend, and doubtless such famines did exist.

Density in particular states. From the reports[1] of the last census it may be inferred that locally we are approaching a condition of maximum density. For example, Rhode Island has 517 people per square mile; Massachusetts has 420; New Jersey, 337; Connecticut, 230; New York, 191; Pennsylvania, 170; Maryland, 131; Ohio, 117; Illinois, 101. In Europe, Belgium has a population of 587 per square mile, and the Netherlands has 408; it is about two thousand years since Roman invasion brought this part of Europe in touch with the westward movement of empire. Less than three centuries have elapsed since a similar movement reached New England.

In the above list, with the exception of Ohio and Illinois, the more densely populated states are east of the Appalachians. Furthermore, they are in the northern section of the Atlantic states, and their density is due not to pastoral or agricultural but to manufacturing conditions. In western civilization maximum density or great density accompanies a strong development

[1] Henry Gannett, "The Population of the United States," *National Geographic Magazine*, vol. xxii, p. 36, 1911.

of the manufacturing industries. This fact is brought out better by the statistics of the percentages of urban population in the above states:

Rhode Island	68
Massachusetts	64
New Jersey	52
Connecticut	45
New York	69
Pennsylvania	39
Maryland	43
Ohio	37
Illinois	46

The order of population density in the first list of states is consecutive; but Maryland is the only state holding the same rank in the list of the percentages of urban population. New York has the largest percentage of urban population, while Ohio has the least.

Pacific coast states in last decade. During the last decade there have been some marked instances of rapid population growth among these states: Washington increased 120 per cent, Idaho 101 per cent, Oregon 63 per cent, California 60 per cent. In the seventeenth and eighteenth centuries a somewhat analogous condition might have been noted on the European side of the Atlantic Ocean, a condition that developed in accordance with Kingsley's slogan "Westward Ho," the industry and commerce of Europe spreading across the seas. In a few decades, at a rate which was marvelous compared with its unfolding in the old world, this movement crossed the United States. Considering the facts of this last decade, the future will witness a more equal division of commercial activity between the Atlantic and the Pacific.

The Pacific states have been sparsely settled for a long time. Nearly three-fourths of a century has elapsed since California took a foremost place as a wealth-producing state, but only in recent years has the area adjacent along the Pacific commenced to show its possibilities. While we have these large figures of population increase in the last decade, at the same time, the density of population in the respective states is not significant: Washington has a density of 17 per square mile, Oregon 7, California 15. The percentages of urban population are as follows: Washington 37 per cent, Oregon 31 per cent, California 45 per cent.

Nevertheless, this rapid growth of the Pacific states is due almost entirely to urban development; only a nominal gain represents the settlement within the last decade of certain well-watered farming districts along the coast and of other sections reached by the irrigation service.

The past, in building up industrial centers along the north Atlantic, produced the states having the greatest density in population, as well as the largest cities. The present, as an index of the future, shows remarkable virility among the Pacific coast states. The markets of the world, if markets are measured by population, front the Pacific; the major part of the world's population looks into the Pacific.

Industry and urban density. Industrial conditions are basal to urban populations. The particular industrial condition that accounts for the high general density in the north Atlantic states, as well as their great urban population, is the presence of water power for energizing manufacturing plants, and the proximity of coal fields. The coal fields of Pennsylvania have been very important in the industrial growth of these states; if the coal had been thousands of miles away, this area, even with its abundant water power, would not contain so many people, and certainly would not have so many large cities; nor would the United States have its present rank among the nations, for the industrial progress of the whole country has fluctuated with that of the Atlantic states.

The limit of rural density. Commencing with the period of settlement, for several decades, according to the decennial statistics of the United States, there was a marked growth of population in the rural districts. Later these districts came to a static condition; then, urban population began to increase, and the gain in population thereafter depended upon the growth of the cities. Thirty or forty years ago the rural population of Ohio had become static, or in a few counties had commenced to decline. Under the prevalent methods of agriculture, the state had reached its maximum in rural population, and its cities, excepting a few, had not yet experienced the modern expansion of manufacturing.

In the last census the term "rural population" includes all villages having less than 2500 inhabitants. Thus "rural" includes slightly more than the farming population.

From 1900 to 1910 the rural population of the state as a whole

declined 1.3 per cent; the percentages of decrease in particular counties were large: Brown, 12.1; Crawford, 11.3; Jackson, 14.3; Meigs, 13.2; Monroe, 13.8; Paulding, 17.4; Pike, 13.5; Vinton, 14.6; Van Wert, 10.4. Only one of these counties, Crawford, gained in gross population; this gain was due to the growth of its only city, Bucyrus.

In certain other counties a marked gain was made in rural population: Athens, 20.1 per cent; Belmont, 31.1; Cuyahoga, 29.6; Guernsey, 13.3; Jefferson, 47.5; Mahoning, 13.8; Summit, 20.1. Each of these counties contains one or more prosperous cities. The population growth of these cities in the particular counties is as follows: Athens county, Athens, 78.1 per cent; Belmont county, Martins Ferry, 17.6, Bellaire, 30.6; Cuyahoga county, Cleveland, 46.9; Guernsey county, Cambridge, 37.4; Jefferson county, Steubenville, 56; Mahoning county, Youngstown, 76.2; Summit county, Akron, 61.6, Barberton, 116.1. This urban activity increased the demand for farm products, which may partly account for the gain in rural population. In the vicinity of the larger cities intensive methods of agriculture are being practised.

Much of the central Mississippi basin during the last decade has shown very slight, if any, gain in population; many of the states have not shown any increase because agriculturally, under the present methods of farming, they have been fully exploited, and the industrial readjustments have only begun to develop manufacturing centers which in time will be large cities. Were it not for the city of Chicago, Illinois would now be in the stagnant class; omitting Chicago, the state has made no growth since 1900.

Urban density in Ohio. The effect of urban concentration appears in the rapid growth of certain cities during the last decade. In New York state the increase of urban population was 42 per cent, and of rural population 2 per cent; in Massachusetts the urban population increased 32 per cent and the rural 4 per cent; in Ohio the urban 48 per cent, while the rural declined 1.3 per cent. There is something significant in the figures of these three states. Industrially, if the growth of urban population is an index, Ohio leads these states in the progress made from 1900 to 1910. Ohio has five cities of over 100,000 in population: Cleveland, Cincinnati, Columbus, Toledo, and Dayton. There

are only two other states, Massachusetts and New York, that have five cities in the 100,000 class. The United States has fifty cities in this class. In the whole country, during the last decade, fourteen cities were added to the 100,000 list. Of the cities thus advanced, some of them present surprising figures: Birmingham, Ala., for example, in the decade ending 1910, increased 245 per cent; Los Angeles, Cal., increased 212 per cent; Seattle, Wash., 194 per cent; Spokane, Wash., 183 per cent; Portland, Ore., 129 per cent; Oakland, Cal., 124 per cent.

During the last decade, Cleveland gained 46.9 per cent, Cincinnati 11.6 per cent, Columbus 44.6 per cent, Toledo 27.8 per cent, Dayton 36.6 per cent. Municipal patriotism is always concerned in these decennial statistics. There is much geography also in these statistics. The growth of Columbus is interesting; its central position in the state, and the ample transportation facilities attract manufacturing.

Ohio's smaller cities. In the list of cities ranging from 25,000 to 100,000, Ohio has nine, as follows:

	INHABITANTS	RATE OF INCREASE IN LAST DECADE
Akron	69,067	61.6
Canton	50,207	63.7
Hamilton	35,279	47.5
Lima	30,508	40.4
Lorain	28,883	80.2
Newark	25,404	39.9
Springfield	46,921	22.7
Youngstown	79,066	76.2
Zanesville	28,026	19.1

The smaller cities of the state have shown the greatest growth in the last decade; this is natural. When a city attains the size of Cleveland, Columbus or Cincinnati, it does not make in a decade such a phenomenal growth as is possible with smaller places. Competition is more rife in these larger centers, and manufacturers looking for places to locate plants, often prefer the smaller places.

Akron, Canton, and Youngstown are along the neck of an hour-glass-shaped area of relatively dense population joining Lake

Erie and the upper Ohio basin. In this region are several other cities which contain over 10,000 population. Geographically that is the liveliest part of Ohio; it is the area to which profit accrues directly and indirectly from the ore and steel business, connecting the Superior mines and western Pennsylvania. Active trade routes are not in operation long before population centers commence to appear along them.

In the next decade, this hour-glass region of Ohio will make just as rapid progress as it has in the last; even if the conditions basal to its industry were changed, its present business momentum would continue several years. But this region is liable to suffer with the decline of the steel business in western Pennsylvania, in case its cities are slow in making the necessary readjustments.

In addition to the cities already mentioned, Ohio has four others, East Liverpool, Mansfield, Portsmouth, and Steubenville, each of which contains between twenty and twenty-five thousand in population; also 18 cities each having between ten and twenty thousand; and 42, ranging from five to ten thousand in population.

PROBLEMS OF LARGE CITIES

Markets and urban density. The concluding part of this discussion has to do with particular problems that are associated with centers of dense population. In large cities markets are generally found; in smaller towns only stores. The market is a response to the advantage of eliminating the greatest possible number of middlemen who stand between producers and consumers. In the market usually the producer and consumer come face to face, the man with the hoe and the woman with the basket, and they discuss prices. Wherever population is congested the most important question of all is food, its quantity, quality, and price. The market helps to keep prices moderate. The chief market-buyers are laboring people and a small percentage of middle folk, the sturdy people of some means, who believe in saving if they can, instead of buying everything over the telephone, and paying the added prices. The market and itinerant hucksters are essential to the welfare of industrial centers. It is important that the actual necessities of life be reasonable in price, because the major part of the population in every large city consists not of bankers, merchants, and professional men, but of laborers.

Water supply and urban density. Each year cities are becoming more concerned over problems of sanitation. Municipalities are not proud of invalids and paupers, even though these figure in census reports. A most important source of disease in cities is the drinking water; the chief duty of municipalities, therefore, is to supply its citizens with pure water. But in practice this duty is not usually recognized till some hygienic disaster arises or till a shamefully high death rate compels them to consider the question of a source of pure water or modern means of purifying the water. The source of the water is some assurance of its condition when it reaches the consumer, but it is no guarantee; filtering and constant vigilance in guarding against organic contamination are necessary.

Sewage disposal and urban density. In most American cities there is opportunity for improvement in the matter of sewage disposal. The prevalent method appears to consider but one object, that is, to get the sewage out of sight as speedily as possible, regardless of the contamination of rivers and other water bodies from which drinking water is secured. Such methods contrast badly with the accomplishments of our civilization in engineering. Many years ago, a citizen[2] of Cleveland read a paper before the Western Reserve Historical Society, in which he discussed with almost prophetic vision this question as related to his city. At that time the Cuyahoga valley proper and all its tributaries were used as outlets of sewers, and the river was left to remove the sewage.

Urban transportation. Congested centers of population should have ample facilities for traveling quickly, conveniently, and cheaply about the city; with speed, because time is valuable; at a reasonable charge, because the laboring people who must go to their work should not be expected to contribute large dividends to transportation companies. Rapid urban transportation of the most modern type does not exist in any Ohio city. A few cities in this state are already so large in area that rapid-transit, preferably by subways, is imperative.

[2] John H. Sargent, *Western Reserve Historical Society*, Tract 82, p. 295, 1891.

THE CLIMATE OF OHIO

FRANK CARNEY

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If you have always lived in what men generally call a good climate, by which, as a rule, they mean uniform conditions of weather, you are as unconscious of it as of the involuntary actions of your body. If, however, you live in a different sort of climate, you are more or less aware of and concerned in the weather changes that may have to do with your whole livelihood. Ohioans sometimes complain very much about the weather, but they are proud of their climate. The term weather refers to the details which, combined, make climate. The sunshine of today and the clouds of yesterday are features of the weather; the general conditions throughout the month or year, or during a long term of years, make up the climate.

There are three important factors in climate: temperature, precipitation, and wind or air pressure. Secondary features associated with some of these three frequently attract much attention. If the temperature is intensely low or intensely high, it may serve to characterize the whole climate, regardless of the

other features. If the precipitation throughout the year is fairly high but all falls in a particular month instead of being distributed with some uniformity through the twelve months, the region may be a desert. If the wind blows always from one quarter instead of varying as it does in Ohio, disagreeable features may be said there to characterize the climate.

TEMPERATURE

As influenced by latitude. Temperature depends very largely on latitude. The latitude regulates the area covered by a unit sunbeam. A sunbeam of a given cross-section area, when the sun stands directly over the equator, will cover on the equator an equal area, but at that same instant, in our latitude, the same area of sunbeam may be spread over twice as much land. In the former case, the energy of the beam is concentrated; in the latter, it is scattered. The sunbeams, passing through the atmosphere, we are told, do not warm the atmosphere, but the temperature of a land area appears to be connected very closely with the temperature of the atmosphere. The atmosphere, therefore, must get its warmth from another source than the sun's rays which pass directly through it. This other source is radiation from the surface of the earth. Sunlight warms the land and the water surfaces, which radiate their heat and warm the atmosphere. Consequently, in those parts of the earth where the sunbeams are more vertical, the surfaces are warmed more, and through radiation the atmosphere adjacent is also kept warmer. In our latitude we never have vertical sun rays, but throughout the year the degree of obliqueness changes very much.

Furthermore, our highest temperatures do not come when the position of the sun gives the least oblique rays, for the reason that the general temperature depends also on the gradual warming of the atmosphere by the continued radiation of surface heat. As a result, the climax of summer is not in the mathematical middle of the summer months, but lags behind; and our lowest winter temperatures follow the middle of the winter months.

During May, we note that the heat received in a particular day by a given area in this latitude is not entirely radiated during the following night. Next morning a slight increment of the previous day's warming remains, and to this will be added the

increment of tomorrow and the next day, so that by the middle of August the land of Ohio is quite warm; for several weeks after the sun's rays become more oblique the atmosphere keeps its summer heat, simply because it is being added to by heat radiated from the land.

As influenced by altitude. Another factor in temperature is altitude. All places on a given parallel do not have the same temperature. A plateau two thousand feet high, adjacent to a lowland belt, will give different readings of a thermometer than will the lowland at the same time of the day. In Ohio the variation in altitude is not sufficiently great to show very marked temperature differences through this factor.

As influenced by bodies of water. A third influence, bearing on temperature, is found in the relationship of land and water areas. This follows from these two forms of matter having different specific heats. Lake Erie and an equal area of the state of Ohio exposed to the same insolation during the same length of time will show different heat results. It takes longer to warm or to cool a body of water, but when its temperature is once changed it remains constant much longer than does an equal area of land. During the winter a water body stores up a great deal of low temperature, which it gives off slowly, and as a consequence keeps the nearby atmosphere cold in the spring, whereas the atmosphere over the neighboring land has already become balmy. Similarly, in the fall the water bodies, having stored up a great amount of summer heat, give it off slowly and keep the air over the adjacent land still moderately warm, while in areas farther away the temperature has already grown cold. A practical result of this last condition is shown in the land areas adjacent to water bodies being devoted to fruit growing, because in the spring the cold of the lake keeps the buds from starting, and the time of late spring frosts has passed before they bloom; in the fall the warmth of the lake retards early frosts, and the fruit has ample time to mature.

Isothermal maps. Men have devised a method of expressing some of the facts of temperature. A temperature map of Ohio during any particular year consists of isotherms, which connect places having the same mean annual temperature. An isothermal map of Ohio, therefore, shows variation, because Ohio stretches through a few degrees of latitude. The range in mean annual temperature varies from six to seven degrees.

PRECIPITATION

There is always moisture in any natural atmosphere, but in order that we may observe this moisture it is necessary that the atmosphere be cooled. A warm atmosphere holds its moisture. An atmosphere at any temperature holds some moisture, that is, it is practically impossible to take all the moisture out of an atmosphere. The form in which precipitation falls depends upon the temperature; below freezing, it comes as water in crystal form; at other times as rain; at still other times, under proper conditions, it collects invisibly, forming, if this collection is kept up long enough, a dew or frost.

Quantity. The quantity of precipitation is in itself not the most important factor about precipitation. For all practical purposes, especially for agriculture, we are concerned more with the seasonal distribution of this precipitation. An area during the year may have forty inches of rain and yet have that rain so distributed seasonally as to make it impossible to grow crops.

Another feature of the atmosphere's moisture is of interest physiologically. An atmosphere which continues to hold a great deal of moisture becomes oppressively humid, and makes work disagreeable, particularly in warm weather; in cold weather, it intensifies the effect of low temperatures.

Seasonal distribution. In Ohio we are interested in precipitation in one other particular. The unequal distribution of rainfall and snowfall gives rise to floods. The earth is not able to soak up the moisture as fast as it comes, and the moisture has to run off. Along the Ohio river this is a matter of industrial concern. Shipping conveniences make it necessary for men to have wharves and buildings well out on the stream. A sudden change of twenty or thirty feet in the depth of that stream necessarily causes loss. If the sudden flood depth is unannounced, disasters follow; the government, therefore, under the direction of the Weather Bureau, times the progress and intensity of these floods, and has made arrangements for keeping the people downstream informed; thus they have an opportunity to protect their property.

A long period of either rain or drought, between early spring and fall, is detrimental to farming interests. Almost every year in some sections of the state, the farmers suffer loss either through

too much or too little rain. But a record of crops for a series of years shows that no particular part of Ohio has any advantage over other parts, in this respect.

WINDS

Someone once said, and the assertion has been current through the centuries, "The wind bloweth where it listeth." The physics of the atmosphere was not well understood in Biblical times. The atmosphere moves according to law. In Ohio we are in the track of a very regular wind belt, the "prevailing westerlies." If the wind always blew from the west, it would grow very monotonous, but the prevailing direction may be from the west and yet a good many variations be introduced. These variations from the prevailing wind give the most interesting phases of this subject.

Cause of air currents. As to their origin, winds are classified under two heads, "highs" and "lows", the names having no connection with their velocity. The atmosphere moves not because there is any external force which gives it impulsion, but because of its tendency to maintain equilibrium. The fluctuation of wind direction represents the effort of the atmosphere to return to a state of equilibrium. There has been an unbalancing somewhere in its body, and the atmosphere is on the move, trying to establish a condition of rest; the unbalancing is due to a difference in the relative weight of adjacent parts of the atmosphere.

The reason why the atmosphere does not, at all places, have a uniform weight is closely connected with the question of heat-radiation from the earth's surface; there may be other causes, but this is known to be one. Take the roof off an ice-house, sweep the sawdust away, and you will cool the nearby atmosphere. That atmosphere, growing cool, becomes heavier; adjacent to it is lighter atmosphere, which the heavier atmosphere displaces. That is the principle of the winds. Somewhere the atmosphere has become heavier and it pushes out; or somewhere the atmosphere has grown warmer and consequently lighter, and it is displaced by the heavier. The movement arising from either cooling or warming is an effort to establish equilibrium. The weather in Ohio, in its variations from day to day, is largely connected with this question of atmospheric density, or high and low pressure areas.

An area of high pressure means that there the barometer registers more than normal. It signifies heavier atmosphere; that heavy atmosphere will move outward, displacing lighter atmosphere. If Columbus is the center of such a high pressure area, over the neighboring land surface the atmosphere is moving outward. A low pressure area signifies atmosphere which is lighter than normal. At some distance from such a center, the atmosphere is always heavier and consequently is moving towards the center upward from which the lighter air is rising.

Weather conditions about cyclonic and anti-cyclonic centers. These storm centers, anti-cyclonic (high pressure) and cyclonic (low pressure) areas, sometimes are very large, not infrequently having a diameter several times that of our state. In that case, the movement of the atmosphere on the surface involves several degrees of latitude, and a corresponding change in temperature so far as it is influenced by latitude. A current of air moving southward from the anti-cyclonic center, warms as it goes; growing warmer, it can hold more and more moisture; consequently, the sky will be clear in the path of the atmosphere which moves southward. According to the same principle, a current of air moving northward from the storm center grows cooler, its moisture commences to show in the sky as clouds, and with further cooling precipitation falls.

With a low pressure area central at Columbus, the atmosphere from all directions moves towards that city. Atmosphere coming from the Kentucky side moves into higher latitude and accordingly is cooled, with clouds and precipitation in that part of the storm area. But atmosphere moving from the northern part of the state to lower latitudes, warms as it goes, and is able not only to hold its own moisture, but to acquire more; on that side of the cyclonic area there will be clear sky.

Over the center of the high pressure area the atmosphere is settling or descending; this increasing pressure keeps the temperature warm or at least constant, hence the sky is clear; whereas at a cyclonic center the air is rising and expanding; thus it cools and precipitation falls.

On account of the earth's rotation the surface air currents about these "high" and "low" centers do not move in a straight line, but are diverted constantly to the right, as they move, in this hemisphere, and to the left, south of the equator. When we

make a plot of the actual movements of the winds of a cyclonic or of an anti-cyclonic area, the diagram resembles a spiral rather than the spokes of a wheel.

Furthermore, these centers are not stationary; they move toward the east. The storm path may have a northern or a southern component in its direction of travel, but the prevailing direction is eastward. The frequency of these storm paths in Ohio increases northward across the state. A large part of the state, however, may be affected by a cyclonic or an anti-cyclonic area whose center takes a course through Lake Erie or even in Canada.

Thus about either of these centers, "high" or "low," we find a variety of conditions: a variation in the thermometer readings, in the register of the barometer, and in the precipitation. A vertical plane drawn through a cyclonic or an anti-cyclonic area in any direction and studied in detail, will emphasize this variety. Because of this fact, Ohio has a variable and interesting climate; the changes are sometimes sudden, but the disagreeable weather does not endure.

Other air currents. Associated with the proximity of land and water bodies are other atmospheric currents, locally important. These are called "land breezes and sea breezes," but in Ohio we find a corresponding phenomenon along Lake Erie. During the period of sunshine the land heats more quickly than does the body of water; the radiated heat warms and consequently lightens the air above the land; the heavier air above the water moves inland, establishing a cool lake breeze. In the late afternoon, the water becoming relatively warmer, a flow of air from the land is established, making a land breeze. In the course of a day the bottom and the walls of a valley are differentially heated, instituting movements of the atmosphere similar in origin to land and sea breezes. It is on this principle that we are advised nowadays never to build houses on the valley bottom nor on the top of a hill, but some distance below the hill top or crest of a ridge; in this location the extremes of heat and cold are more moderate.

CLIMATOLOGY

Our Government excels all others in the scientific study of the climate; nevertheless we have a paucity of students of clima-

tology, however contradictory these two facts may appear to be. Germany probably has the most thorough record-investigators of climate, but the German government does not do for this science what our government is doing yearly. Our Weather Bureau is the envy of all students of climatology. Facts pertaining to weather data have right of way on the telegraph wires of this country for a certain period every day. In European countries, where militarism usually can accomplish arbitrarily what it wishes, they have not yet been able to secure for weather data the necessary special privileges in the telegraph system. The United States can marshal an array of weather data for a given period of years that is not equalled by any other government.

Early development in America. No discussion of climatology in the United States, and especially a discussion that pertains to the Buckeye State, is complete without alluding to the fact that the first weather maps issued in this country were published at Cincinnati. Cleveland Abbe, the leading American student of climatology today, aided by the Cincinnati Chamber of Commerce, in 1869 instituted the first weather service. Through certain voluntary efforts of associates, Mr. Abbe collected data as near and as far from Cincinnati as he could get it, and on the basis of this data he published information about the weather. The following year the Federal government organized a national service under the War Department. In 1891 this meteorological work was transferred to the Department of Agriculture, as the Weather Bureau. Cleveland Abbe has been associated with American climatology from its beginning; the work he did while Director of the Cincinnati Observatory gives the subject special historical interest.

WEATHER BUREAU SERVICE IN OHIO

The three districts. Our state is divided into three sections, the Northern, Middle and Southern. By defining the Middle section we have the others properly distinguished. The northern margin of the middle section begins on the east with the northern boundary of Columbiana county, and follows due west the nearest county line, ending with the northern boundary of Van Wert county; the southern margin starts with the northern boundary of Monroe county, and proceeds westward to the northern boundary

of Preble county. In a rough way, these are latitude divisions, and as such are pertinent to any study of the weather.

Period of observations. Meteorological work proceeds from observations, usually instrumental, therefore accurate, not approximate. Few people can guess within several degrees the temperature at any given time. We have in Ohio two classes of weather observers, one salaried, the other volunteer; only in connection with the Weather Bureau stations are men employed on salary. It is a praiseworthy fact that in some places records covering nearly a century's observations, at least on temperature and precipitation, are available. In the following places weather data have been tabulated for the number of years designated:

Northern section

LOCATION	TEMPERATURE	PRECIPITATION
	years	*years*
Bangorville, Richland county	24	24
Bowling Green, Wood county		30
Cleveland, Cuyahoga county	40	40
Hudson, Summit county		50
Oberlin, Lorain county	28	36
Sandusky, Erie county	34	34
Toledo, Lucas county	40	50
Wauseon, Fulton county	41	39

Middle section

Bellefontaine, Logan county	17	32
Columbus, Franklin county	33	33
Granville, Licking county	25	29
Ohio State University	28	28
Sidney, Shelby county	23	28
Urbana, Champaign county	15	43

Southern section

Cincinnati, Hamilton county	39	40
Dayton, Montgomery county	38	30
Hillsboro, Highland county	12	32
Marietta, Washington county	67	91
Portsmouth, Scioto county	80	80
Waverly, Pike county	28	

Weather Bureau stations. In each section the government maintains also regular Weather Bureau stations. In the Northern section there are three: at Cleveland, Sandusky, and Toledo; in the Middle section a station is maintained at Columbus; in the Southern section, one at Cincinnati.

The value of a volunteer observer's data depends on his training and the instruments he has at his disposal. As a usual thing, the Federal government does not send out a very complete equipment of instruments to be handled by a volunteer observer. The regular Weather Bureau stations record very complete weather data; they measure the precipitation, tabulate the wind direction and velocity for every minute of the twenty-four hours of the day; tabulate the periods of sunshine and cloud during the day; record the dates of appearances of frosts, and the velocity of particular storms, if unusual. Much of this is done automatically. Man is not sufficiently discerning or accurate to do some of these things; instead he has invented machinery that will do the work correctly.

Illustrative records. The volunteer observers report periodically to a Weather Bureau station. The data collected by the larger number of people who are working just for the love of it, together with the data of the regular stations, characterizes the weather of Ohio, and for the period concerned is a basis for describing its climate. The results may be illustrated by reference to particular weather phenomena for a given period. For the year that closed in December, 1910, the mean annual temperature in the Northern section was 49.1°; in the Middle section, 50.6°; in the Southern section, 52.6°; for the whole state, 50.4°. But these facts are of little value unless we have some average or normal with which to compare the data. The normal temperature for the Northern section is 50.1°; for the Middle section, 50.9°; for the Southern section, 52.9°; for the whole state, 50.7°.

The weather of Ohio, as already stated, is not monotonous; comparing one year with another we note the variation. The mean annual temperature in 1909 for the three sections and the whole state, in order, was 49.4°, 51°, 53.4°, and 50.9°. Last year was cooler than usual, while the preceding year was more than usually warm.

But there is another fact always of great consequence in temperature conditions, that is, the temperature range. In 1910, in

Ohio, there was a temperature range of 125°. The physiological effects of being transferred suddenly through such a temperature range would be bad; but the extremes are in different seasons. August 17, 1910, at Vickery, the official thermometer registered 100°. On February 19, 1910, at Bladensburg, the official thermometer registered −25°. The temperature range the preceding year was only 117°; the highest temperature, 97°, being noted at New Alexandria, July 30, while the lowest temperature, −20°, was recorded at Bellefontaine, December 30.